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Engineering Library

ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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VOL. CXIII.—No. 2942.] *LONDON: FRIDAY, MAY 19, 1922.* [*Registered at the General Post Office as a Newspaper.*] [PRICE ... 1s. BY FOREIGN POST 1s. 3½d.

Aveling & Porter, Ltd.,
ROCHESTER.
9663
Steam Road Rollers & Tractors.

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CULVER STREET WORKS, COLCHESTER.
ON ADMIRALTY AND WAR OFFICE LISTS.
ENGINES for Torpedo Boats, Yachts, Launches.
BOILER FEED PUMPS.
See advertisement pages 29 and 63.
PATENT WATER-TUBE BOILERS,
AUTOMATIC FEED REGULATORS.
And Auxiliary Machinery as supplied to the Admiralty. 2170

Dredging Plant
OF ALL DESCRIPTIONS.
FLOATING CRANES. COAL BUNKERING VESSELS.
Werf Conrad, HAARLEM, HOLLAND.
Agents: MARINE WORKS, LTD., FRIARS HOUSE, 39-41, NEW BROAD ST., LONDON, E.C.2.
See half-page Advert. last week and next week. 675

Cranes.—Electric, Steam,
HYDRAULIC and HAND,
of all types and sizes.
GEORGE RUSSELL & CO., LTD., Motherwell, near Glasgow. 9048

STEEL TANKS, PIPES, GASHOLDERS, &c.
Thos. Piggott & Co., Limited,
BIRMINGHAM. 7411
See Advertisement last week, page 91.

"Spencer-Hopwood" Patent *See page 76.*
WATER TUBE **Boilers.** 677
Sole Makers: SPENCER-BONNECOURT, LTD., Parliament Mansions, Victoria St., London, S.W.

Tank Locomotives.
Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO. LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 9044

Cochran MULTITUBULAR AND CROSS-TUBE TYPES. **Boilers.**
See page 17. 9047

Petter Oil Engines.
For Paraffin and Crude Oil.
Sizes 1½ B.HP. and upwards.
Petters Limited, Yeovil.
Sizes 25 to 300 B.HP.
Vickers-Petters, Ltd., Ipswich
See advertisement alternate weeks. 9035

Invincible Gauge Glasses.
BUTTERWORTH BROS., Ltd.,
Newton Heath Glass Works,
Manchester. Od 9743

Electric Cranes.
9663
S. H. HEYWOOD & CO., LTD., REDDISH.

Fuller, Horsey, Sons & Cassell.
SPECIALISTS
in the
SALE AND VALUATION
of 1834
PLANT AND MACHINERY
and
ENGINEERING WORKS.
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Iron and Steel
Tubes and Fittings.
Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes.
The Scottish Tube Co., Ltd.,
HEAD OFFICE: 24, Robertson Street, Glasgow.
See Advertisement page 75, May 12.

Yarrow & Co. (1922), Ltd.,
SHIPBUILDERS AND ENGINEERS, GLASGOW.
SPEEDS UP TO 45 MILES AN HOUR.
PADDLE OR SCREW STEAMERS OF EXCEPTIONAL SHALLOW DRAUGHT.
Repairs on Pacific Coast
by YARROWS, LIMITED, Victoria, British Columbia. 9063
SHIPBUILDERS, SHIP REPAIRERS AND ENGINEERS.

Campbells & Hunter, Ltd.
Gear Cutting.
Worm Wheels cut up to 13 ft. diam.
Bevel and Mitre Wheels planed up to 3 ft. diam.
Spur Wheels cut up to 9 ft. diam.
DOLPHIN FOUNDRY, LEEDS. 4547

VOSPER & CO., LTD.,
PORTSMOUTH.
SHIP & LAUNCH BUILDERS, Od 2461
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LTD., Consulting Cement Engineers, ADVISE GENERALLY on proposed Cement Schemes FOR ENGLAND AND ABROAD. ADVICE ONLY. Highest references. Established 1900.
Address, BURNETT AVENUE, HULL.
Cablegrams: "Energy, Hull." 9769

OIL FUEL APPLIANCES,
Systems
PRESSURE, AIR, STEAM
For Boilers of all types.
KERMODES LIMITED,
35, The Temple, Dale Street, Liverpool.
Naval Outfits a Speciality, also for Merchant Ships, for Factories, Locomotives, and Industrial Process Furnaces of all kinds.
Supplied to the British and other Governments.
Telephone No.: Central 2832.
Telegrams: "Warmth." 4078

Locomotives Tank Engines
designed and constructed by
MANNING, WARDLE AND COMPANY, LIMITED, Boyne Engine Works, Leeds. Od 2467
See their Illus. Advertisement, page 95, last week.
RAILWAY AND TRAMWAY ROLLING STOCK.
Hurst, Nelson & Co., Ltd.
THE GLASGOW ROLLING STOCK AND PLANT WORKS. MOTHERWELL. Od 2562

R. Y. Pickering & Co., Ltd.,
(ESTABLISHED 1864.)
BUILDERS of RAILWAY CARRIAGES & WAGONS.
MAKERS of WHEELS and AXLES of all kinds.
RAILWAY WAGONS FOR HIRE.
Chief Works and Offices:
WISHAW, near GLASGOW.
London Office: Od 8353
3, VICTORIA STREET, WESTMINSTER, S.W.

Henry Butcher & Co.,
AUCTIONEERS, VALUERS AND SURVEYORS
for
ENGINEERING AND ALLIED TRADES
and
INDUSTRIAL PROPERTIES. 9066
63 and 64, CHANCERY LANE, LONDON, W.C.2.

Electric Transporters.
S. H. HEYWOOD & CO., LTD., 9663
REDDISH.

John H. Wilson & Co., Ltd.,
Birkenhead.
See Illustrated Advertisement Page 139, Jan. 20, 1922.

Locomotive Shunting Cranes

Steam and Electric Cranes
EXCAVATORS, CRANE-HAVVIES, GRABS, CONCRETE-MIXERS,
SHIPS' WINDLASSES, WINCHES, and DECK MACHINERY.
LISTS OF STANDARD SIZES ON APPLICATION. 657
London Office: 15, VICTORIA STREET, S.W.1.

John Bellamy, Limited,
MILLWALL, LONDON, E. 1216
GENERAL CONSTRUCTIONAL ENGINEERS,
Boilers, Tanks, & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETED STEAM AND VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

Tubes and Fittings.

Stewarts and Lloyds, Ltd.,
Glasgow and Birmingham.
See Advertisement page 54. 9049

Economy!
HIGH BOILER EFFICIENCIES
ARE OBTAINED BY INSTALLING
Todd Oil Burners
FUEL OIL BURNING SYSTEMS.
HEATERS, STRAINERS.
49-51, EASTCHEAP, LONDON, E.C. 3.
TODD SHIPYARDS CORPORATION,
Builders of Steam and Motor Ships, Repairers, Electric Drive Installations.
Twenty-one Floating Docks, Two Graving Docks, Twelve Shipways.
25, Broadway, New York, U.S.A. 9060

The Glasgow Railway Engineering Company,
GOVAN, GLASGOW. LTD.,
London Office—12, Victoria Street, S.W.
MANUFACTURERS OF
RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
CARRIAGE & WAGON IRONWORK, also CAST-STEEL AXLE BOXES. 540

FOR
Drop Forgings
write
GARTSHERRIE ENGINEERING & FORGE CO., 20, Wellington Street, Glasgow. 9074

ON ADMIRALTY LIST.
John Kirkaldy, Ltd.,
London Office: 101, LEADENHALL ST., E.C.3.
Works: BURNT MILL, near HARLOW, ESSEX.
Makers of
Evaporating and Distilling Plants.
Refrigerating and Ice Making Machinery.
Feed Water Heaters.
Evaporators.
Fresh Water Distillers.
Main Feed Pumps.
Combined Circulating and Air Pumps.
Auxiliary Surface Condensers.
&c. &c. 9404

Electric Lifts
(UP TO 25 TONS.)
9663
S. H. HEYWOOD & CO., LTD. REDDISH.

Hardening & Heat Treatment.
Any class of tools. H. S. Chasers for adjustable die heads. Case hardening, colouring, etc. We can case harden Cast Iron for gauges, press tools, etc. Write us for particulars, Reliable Work! Right Prices! Delivery to promise!
OWEN & CRISP,
Engineers and Engineers' Agents,
64, Basinghall Street, London, E.C. 2.
Telephone:—London Wall 5606. 9650

Diesel Engines, Six Cylinder,
Two and Four stroke, 350, 1000, 1200 HP., excellent condition. Dynamos for above 250 or 500 volts, D.C. Immediate delivery and low price.
Two 500 Kw. Parsons Turbine Sets, 250 or 500 volts, D.C., with condensing plant and spare armature. Price £2250.
Electrical driven Centrifugal, Ram and other Pumps from 1½ in.-10 in. outlet.
JENNINGS, 9743
West Walls, Newcastle-on-Tyne.

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, STEAM AND GAS KETTLES, } ROW'S PATENTS.
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 9728

Yarrow Patent Water-tube Boilers.
9564
Messrs. YARROW & CO., UNDERTAKE the PRESSING and MACHINING of the various parts of Yarrow Boilers, such as the Steam Drums, Water Pockets, and Superheaters for British and Foreign Firms not having the necessary facilities.
YARROW & CO. (1922), LTD., SCOTSTOUN, GLASGOW.

Matthew Paul & Co., Ltd.
LEVENFORD WORKS, **Dumbarton.** 9618
See Full Page Advt., page 48, April 28.

Forgings.
Walter Somers, Limited,
HALESOWEN. 7116

Head, Wrightson & Co.,
LIMITED.
See Advertisement page 56. 2492

Taylor & Challen Presses
9199
About 200 NEW PRESSES in Stock in our Showrooms for immediate delivery at specially Reduced Prices.
TAYLOR & CHALLEN, LTD., Engineers, Constitution Hill, BIRMINGHAM.
See Full page Advertisement, page 66, April 28.

Railway Switches and Crossings.
T. SUMMERSON & SONS, LIMITED, DARLINGTON. 800

GRAPHITED OIL. **"OILDAG"** (Reg.) BRAND.
GRAPHITED WATER. **"AQUADAG"** (Reg.) BRAND.
GRAPHITED GREASE. **"GREDAG"**
9508
E. G. Acheson Ltd.,
Dept. R., (Sole Manufacturers.) 40, Wood St., S.W.1. Works: PLYMOUTH.

Locomotive Traversers
(ELECTRIC).
9663
S. H. HEYWOOD & CO., LTD., REDDISH.

P. & W. MacLellan, Limited,
CLUTHA WORKS, GLASGOW.
MANUFACTURERS OF
RAILWAY CARRIAGES AND WAGONS
OF EVERY DESCRIPTION.
RAILWAY IRONWORK, BRIDGES, ROOFING, &c.
Chief Offices: 120, Trongate, GLASGOW. Od 2547
Registered Offices: Clutha House, 10, Princes St., Westminster, London, S.W.1.

Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND.
9737
See half-page Advertisement page 40, May 12.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by SIR WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 598

1921 B. No. 6597.

IN THE HIGH COURT OF JUSTICE,
CHANCERY DIVISION,
MR. JUSTICE SARGANT.
IN THE MATTER OF LETTERS PATENT No. 12801 of the year 1906, granted to SUMMERS BROWN, of 49, Whitecross Street, E.C.
and
IN THE MATTER OF THE PATENTS AND DESIGNS ACTS, 1907 and 1919.

Notice is Hereby Given that

SUMMERS BROWN of 36 Bedford Street Strand in the County of London and RONEO LIMITED whose registered office is situate at 5-11 Holborn in the City of London have by Originating Summons dated the 30th day of November 1921 applied that the term of the above mentioned Letters Patent may be extended.
And Notice is Hereby Given that on Tuesday the 27th day of June 1922 application will be made to the Court that a day may be fixed before which the said Summons shall not be in the Paper for hearing.
And Notice is Hereby Given that any person desirous of being heard in opposition to the said Originating Summons must at least seven days before the said 27th day of June 1922 lodge such notice of opposition in the Chambers of Mr. Justice Sargant, Room 147, Royal Courts of Justice Strand London and serve a copy thereof upon the undersigned F. P. WOODCOCK the Applicants' Soliciter or Agent. And Notice is Hereby Further Given that the address of the undersigned F. P. Woodcock is the address for service on the Applicants Summers Brown and Roneo Limited of any documents requiring service upon them in accordance with Order 55a Rule 3a of the Supreme Court.
Dated this 15th day of May 1922.
F. P. WOODCOCK,
5, Holborn, E.C. 1.
Applicants' Soliciter. U 263

THE SOUTH WALES INSTITUTE OF ENGINEERS.

Engineering Exhibition, at

THE DRILL HALL, CARDIFF, MONDAY, NOVEMBER 20TH, to SATURDAY, NOVEMBER 25TH, 1922 (both dates inclusive).
THE COUNCIL OF THE SOUTH WALES INSTITUTE OF ENGINEERS has decided to hold an ENGINEERING EXHIBITION, at THE DRILL HALL, CARDIFF, during the week commencing NOVEMBER 20TH, 1922.
Each morning a Conference will be held at the Institution, Park Place, Cardiff, when Short Papers on subjects connected with the Exhibition will be read and discussed. Offers of such Papers would be welcomed.
The Exhibition will be opened each day at Two o'clock p.m.
The Exhibition will comprise the following Sections:—

SECTION 1.
Scientific, Measuring and Recording Instruments, as applied to all branches of engineering.
SECTION 2.—STEAM SECTION.
Water Softening and Cooling Plant. Boilers and Equipment. Oil Burners. Pipes, Valves, Separators, etc.
Drawings of Models of Modern Engines. Governors and Safety Devices.
SECTION 3.—ELECTRICAL SECTION.
Switchgear, Cables, Controllers, etc. Overhead Lines. Electrical Tools and other Appliances. Small Motors. Electric Cranes. Telephone and Wireless Apparatus.
SECTION 4.—MECHANICAL SECTION.
Mechanical Transmission of Power. Bearings, Clutches, Ropes, Belts, Gearing, etc.
SECTION 5.—WORKSHOP APPLIANCES.
Machine Tools (small). Pneumatic Tools. Hydraulic Tools.
SECTION 6.—MINING & GENERAL INDUSTRIAL SECTION.
Shaft Signalling. Devices to prevent overwinding. Models of Pit Cages and Tram Tipplers. Pumping Plant. Steel Castings (limited in size and weight). Models of Screening Plant. Models of Coke-Ovens, By-Product and Recovery Plant. Coal Cutting and Conveying Machines. Works Equipment specially applicable to Ship Repairing, Steel, Tin Plate, Cement and Patent Fuel Manufacture.
Manufacturers desirous of taking part in the Exhibition are requested to write to the SECRETARY, The South Wales Institute of Engineers, Park Place, Cardiff, who will furnish information and conditions, and also a Form of Application. U 264

Correspondence Courses for

Inst. Civil Engrs., Inst. Mech. E., London Univ. (Matric., Inter., B.Sc.), and ALL ENGINEERING EXAMINATIONS personally conducted by MR. TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., &c. Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to S/11, TRAFFORD CHAMBERS, 56, SOUTH JOHN STREET, LIVERPOOL. 576

Inst. C.E., I. Mech. E., B.Sc.,

and all Engineering Examinations.—Mr. G. P. KNOWLES, B.Sc., M.I.E., A.M.Inst.C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Thousands of successes during the last sixteen years. Courses may commence at any time.—29, Victoria St., Westminster, S.W. Tel. 4780 Victoria. 746

Inst. C.E. Exams.—Successes

as usual last Exam. by Correspondence Coaching. Successes by hundreds, several prizes. Sec. "S" embraces 26 years' professional experience. Address, 7494, Offices of ENGINEERING.

Powering of Vessels.—A

Practical Course of Instruction by Correspondence.—Address, for particulars and terms, 748, Offices of ENGINEERING.

I. C. Robertson, Final Year

Glasgow, B.Sc. (Engineering), would Coach for Inst. C.E. Examinations in Civil Engineering, Surveying, Public Works, Geology and French.—38, Westmount Road, Eltham. U 245

TENDERS.

THE METROPOLITAN ASYLUMS BOARD invite

Tenders for the Opening Up,

REPAIRING and CLOSING UP of the ENGINES, etc., of the RIVER AMBULANCE STEAMER "RED CROSS" in accordance with the specification prepared by Mr. THOMAS COOPER, M.I.C.E., Engineer-in-Chief to the Board.
Specification, conditions of contract and form of Tender may be obtained at the Office of the Board, Embankment, E.C. 4.
Tenders addressed as noted on the form must be delivered at the Office of the Board, not later than Ten a.m. on Monday, 29th May, 1922.
DUNCOMBE MANN,
Clerk to the Board.
12th May, 1922. U 231

RUGBY URBAN DISTRICT COUNCIL.

TO ENGINEERS, METAL MERCHANTS, AND OTHERS.

The Water Committee of the above Council invite

Offers for Two Babcock and

Willcox BOILERS with Fittings, &c., as they stand.
These may be seen at the Avon Water Works, Brownsover Mill Road, Rugby, on any day by appointment, between the hours of Ten a.m. and Five p.m., except Saturdays or Sundays.
Offers, endorsed "Boilers," to be addressed to the undersigned and delivered at his office, not later than Monday Noon, the 29th inst.
JOHN H. SHARP,
Water Engineer.
Benn Buildings, Rugby,
3rd May, 1922. U 164

METROPOLITAN WATER BOARD.

The Metropolitan Water Board invites

Tenders for the Supply,

TESTING and SETTING TO WORK OF A STEAM DRIVEN LOCOMOTIVE SHUNTING JIB CRANE of 4 to 5 tons capacity at the BATTERSEA PUMPING STATION (South Lambeth Sidings, G.W.Ry.).
Forms of Tender, Conditions of Contract, etc., may be obtained on application at the Offices of the Board (Room 150), 173, Rosebery Avenue, E.C., by personal application or upon forwarding a stamped and addressed brief envelope. Tenders enclosed in sealed envelopes addressed to "The Clerk of the Board, Metropolitan Water Board, New River Head, 173, Rosebery Avenue, E.C. 1," and endorsed "Tender for Loco. Crane," must be delivered at the Offices of the Board not later than Ten a.m. on Friday, 2nd June, 1922. The Board do not bind themselves to accept the lowest or any tender.
W. MOON,
Clerk of the Board.
Offices of the Board,
New River Head,
173, Rosebery Avenue,
Clerkenwell, E.C. 1.
16th May, 1922. U 256

METROPOLITAN WATER BOARD.

TENDERS FOR THE SUPPLY AND FIXING OF STEEL STEAM PIPES AND VALVES AT KEW BRIDGE WORKS.

The Metropolitan Water Board invite

Tenders for the Supply and

FIXING of WROUGHT STEEL STEAM PIPES, with STOPVALVES, at their Kew Bridge Works, Brentford, Middlesex.
Forms of Tender, Conditions of Contract, Specification and Drawing may be inspected without payment of fee at the offices of the Board (Room 150), 173, Rosebery Avenue, Clerkenwell, E.C. 1, on and after Tuesday, 23rd May, 1922.
Contractors desirous of tendering may obtain the necessary documents from Mr. HENRY E. STILGOE, M.Inst.C.E., the Chief Engineer, on production of an official receipt for the sum of £1 1s., which sum must be deposited with the Board's Accountant and will be returned on receipt of a *bona fide* Tender, together with all incidental papers.
Such payments and applications must be made between the hours of Ten a.m. and Four p.m., Thursday excepted (Saturdays Ten a.m. to Twelve noon).
Tenders enclosed in sealed envelopes addressed to "The Clerk of the Board, Metropolitan Water Board, 173, Rosebery Avenue, E.C. 1," and endorsed "Tender for Steam Pipes, Kew Bridge Works," must be delivered at the Offices of the Board not later than Ten a.m. on Wednesday, 31st May, 1922.
W. MOON,
Clerk of the Board.
Offices of the Board,
173, Rosebery Avenue, E.C. 1.
May, 1922. U 237

COUNTY BOROUGH OF CROYDON.

SURREY STREET WATERWORKS.

TO ENGINEERS.

NOTICE IS HEREBY GIVEN that the Council are prepared to receive

Tenders for the Supply, Fixing

and SETTING TO WORK of a STEAM PUMPING ENGINE at the Surrey Street Waterworks. Specification, Conditions and Form of Tender may be obtained on application at the Borough Engineer's Office, Town Hall, Croydon, upon payment of a deposit of One Guinea, which will be returned upon receipt of a *bona fide* Tender.
Tenders on the prescribed form to be sent to me by Eleven o'clock in the forenoon of Saturday the 1st day of July, 1922, endorsed "Tender for Pumping Plant, Surrey Street Waterworks."
Tenders will only be received subject to the terms of the draft Contract and Conditions deposited at my office and which may be inspected during Office Hours.
The Council will not be bound to accept the lowest or any Tender.
JOHN M. NEWNHAM,
Town Clerk.
Town Hall, Croydon.
16th May, 1922. U 217

THE HIGH COMMISSIONER FOR INDIA is prepared to receive

Tenders for the Supply

of:—
1. GAS ENGINE, Horizontal, Single Cylinder, and GENERATOR.
2. SCALES AND MACHINES, Weighing.
3. MACHINES, Lithographic, Rotary.
4. TIN SHEETS.
5. SPRINGS, Helical and Volute, for Engines, etc.
6. WIRE, Copper, Telegraph.
7. CABLE, Electric, V.I.R. insulated.

Forms of Tender may be obtained from the Director-General, India Store Department, Belvedere Road, Lambeth, S.E. 1, and Tenders are to be delivered at that Office not later than Two o'clock p.m. on Friday, the 2nd June, 1922, for Nos. 1 to 4, on Friday, the 9th June, 1922, for Nos. 6 and 7, and on Tuesday, the 30th May, 1922, for No. 5.
T. RYAN,
Director-General. U 222

VENTNOR URBAN DISTRICT COUNCIL.

REPAIRS TO TIE RODS, &c., TO THE ROYAL VICTORIA PIER AND LANDING STAGE.

The Ventnor Urban District Council invite

Tenders for the Repair and

REPLACEMENT of a number of TIE RODS and OTHER IRONWORK to the understructure of the Royal Victoria Pier and Landing Stage, Ventnor.
Plans, Sections and Specification may be seen at the office of Mr. D. V. HOWARD, the Engineer and Surveyor to the Council, Town Hall, Ventnor, I.W.
Tenders, sealed and endorsed "Pier Repairs," to be delivered to the undersigned not later than noon on the 7th day of June, 1922.
The Council do not bind themselves to accept the lowest or any Tender.
(Signed)
JAMES WEARING,
Clerk to the Council.
Town Hall, Ventnor, I.W.,
May 10, 1922. U 196

McHAFFIE & COMPANY, LIMITED
(In Liquidation),
Tinsmiths and Sheet Metal Workers,
61, Well Road,
GLASGOW.

The Subscriber invites

Offers for the Purchase as a

Going Concern of the BUSINESS of TINSMITHS AND SHEET METAL WORKERS, Manufacturers of Kegs and Drums, Plain and Decorated Tin Boxes, &c., and Art Printers on Metal, at present being carried on by McHAFFIE AND COMPANY, Limited (in Liquidation), at 61, Well Road, Glasgow, including the whole Buildings, Electric Lift, Machinery and Plant, Tools, Dies, Stock, &c.
The Buildings, which have recently been erected, are of the most up-to-date design and cover an area of 2,880 square yards or thereby.
The feu-duty is nominal; being £31 8s. 4d. per annum.
The machinery is of the latest automatic producing type, manufactured by the Adams Pressure Tool Company, while the Printing Plant is modern and by the best Makers.
The Motor Power is by electric current obtained from the Glasgow Corporation, and there is a full range of Gas Stoves for Printed Tins.
The premises are centrally situated and are capable of a large production.
There is at present a steady business in Kegs and Drums which might be largely improved upon, while an important Printed Tin business in Scotland might be developed.
Orders to view the Works can be obtained from the Subscriber, or Messrs. WRIGHT, JOHNSTONE AND MCKENZIE, Writers, 150, St. Vincent Street, Glasgow. Sealed Offers, in writing, are to be lodged on or before Twelve Noon on Wednesday, 31st May, 1922, with the Liquidator, who does not bind himself to accept the highest or any Offer.
J. ALLISON, Junr., C.A.,
219, St. Vincent Street, Liquidator.
Glasgow. U 207

STATE ELECTRICITY COMMISSION OF VICTORIA.

TENDERS FOR PLANT.

Tenders are Hereby

Invited for the SUPPLY, DELIVERY, &c., of the following for the Morwell Power Scheme:—
Copies of Tender Forms and Specifications will be available upon application to:—
AGENT GENERAL FOR VICTORIA,
Melbourne Place,
Strand,
London, W.C. 2.

SPECIFICATION No. 226:—
Item 1.—FIVE SURFACE-FEED WATER HEATERS:—Two of 2250 sq. ft. surface; Three of 1450 sq. ft. surface.
Item 2.—SIX SURFACE VAPOUR CONDENSERS, each 165 sq. ft. surface.
SPECIFICATION No. 227:—
Item 1. TWELVE FEED WATER EVAPORATORS, preferably of the marine type supplied with steam at 40 lbs. per sq. inch to operate in groups and multiple effect, four effects producing 12,500 lbs. per hour.
CHARGE (in each instance):—
£2 2s. for the first two copies of Tender Form, Conditions of Contract, Specification and Drawings complete. These charges will be returned on receipt of a *bona fide* Tender. A third copy and any further copies will be supplied for the sum of 10s. 6d. each.
PRELIMINARY DEPOSIT:—
A Preliminary Deposit of £50 is to be lodged with Tender in each case.
The Specifications may be inspected at the above-mentioned Office.
The Commission does not bind itself to accept the lowest or any Tender.
Tenders on prescribed forms, properly endorsed and addressed, must be delivered to the undersigned in Melbourne not later than Five p.m. on 1st September, 1922:—
R. LIDDELOW, Secretary,
STATE ELECTRICITY COMMISSION OF VICTORIA,
673, Bourke Street,
MELBOURNE,
Victoria, Australia. U 239

Wanted, in Good Condition,

a Secondhand SPRING TESTING MACHINE, to test leaf Springs 5 ft. 6 in. centres up to five tons max. load, and supplied with the necessary fitments for testing in compression coil springs up to 18 in. long, and in tension up to 3 ft. max. lengths.
Tenders, containing full particulars, to be addressed, U 250, Offices of ENGINEERING.

Tenders are Invited by

the GOVERNMENT of NEW SOUTH WALES for the CONSTRUCTION of the SUPERSTRUCTURE and SUBSTRUCTURE of a CANTILEVER BRIDGE ACROSS SYDNEY HARBOUR from DAWES POINT to MILSON'S POINT, embracing a main span of 1600 ft. in the clear, centre to centre of main piers, or 2000 ft. centre to centre of anchor piers. The total length of bridge included in tender is 3816 ft., centre to centre of abutments. The deck of the bridge is to include four lines of railway, and a roadway 35 ft. wide, between main trusses; and cantilevered outside the main trusses on the western side, a footway 15 ft. wide, and on the eastern side a motor roadway 18 ft. wide. Copies of specification, including plans, general conditions, and schedule of quantities may be obtained on application to the undersigned.
To give any information required by Tenderers, Mr. J. J. C. BRADFIELD, Chief Engineer, will be in London during June and July, 1922, address care of the undersigned.
Tenders in accordance with the specification must reach the Under Secretary for Public Works, Sydney, not later than 31st October, 1922.
AGENT-GENERAL
FOR NEW SOUTH WALES.
Australia House, Strand, London, W.C. 2.
December, 1921. T 34

APPOINTMENTS OPEN.

BIRKENHEAD EDUCATION COMMITTEE.

HOLT TECHNICAL SCHOOL.

Required, in September Next,

a FULL-TIME LECTURER in Electrical Science, including Elementary Engineering Science. Commencing Salary, £300 per annum.
A list of duties will be forwarded on application to the undersigned, to whom applications, accompanied by not more than three testimonials (together with the names of three gentlemen who may be referred to as to the applicant's teaching qualifications, etc.), must be sent not later than the 10th June, 1922.
Canvassing will be considered a disqualification.
ROBERT T. JONES, Secretary.
Town Hall, Birkenhead,
15th May, 1922. U 274

UNIVERSITY OF BIRMINGHAM.

FACULTY OF SCIENCE.

ASSISTANT LECTURER AND DEMONSTRATOR IN METALLURGY.

GRADE III.

The Council invites

Applications for the above

POST. Commencing stipend £300 per annum.
Applications, accompanied by three testimonials, should be sent to the undersigned not later than the 14th of June. No special form of application is required. Research graduate, with works experience in steel, preferred.
The Candidate elected will be required to enter upon his duties on the 1st of September.
The conditions of appointment for Grade III and for promotion to Grade II on the University Staff may be obtained from:
GEO. H. MORLEY,
Secretary. U 245

Works Manager Required in

Midlands for important Bridge, Constructional, and General Engineering Works; thoroughly capable all-round man with previous experience and full knowledge labour prices.—Address, U 273, Offices of ENGINEERING.

General Manager.—Wanted,

Smart, Energetic MAN accustomed to control staff and workmen. Knowledge of Chemistry, Engineering or Mining advantageous. Salary about £2,000 per annum.—Send experience and testimonials to BOX F.P.V., care of DAVIES & CO., 95, Bishopsgate, E.C. 2. U 215

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MANAGER for Works manufacturing A.C. Motors. Similar experience and technical training essential. Age not over 35.—Write, stating age, experience, training and salary required, to F. & A. PARKINSON, LTD., Guiseley, near Leeds, marking envelope "Assistant Works Manager." U 238

Manager's Assistant in Engi-

neering firm.—WANTED, a GENTLEMAN of Public School education with good commercial experience and some Engineering knowledge to assist Managing Director. Permanent and progressive position to suitable man. Age, 27-30.—Address, U 229, Offices of ENGINEERING.

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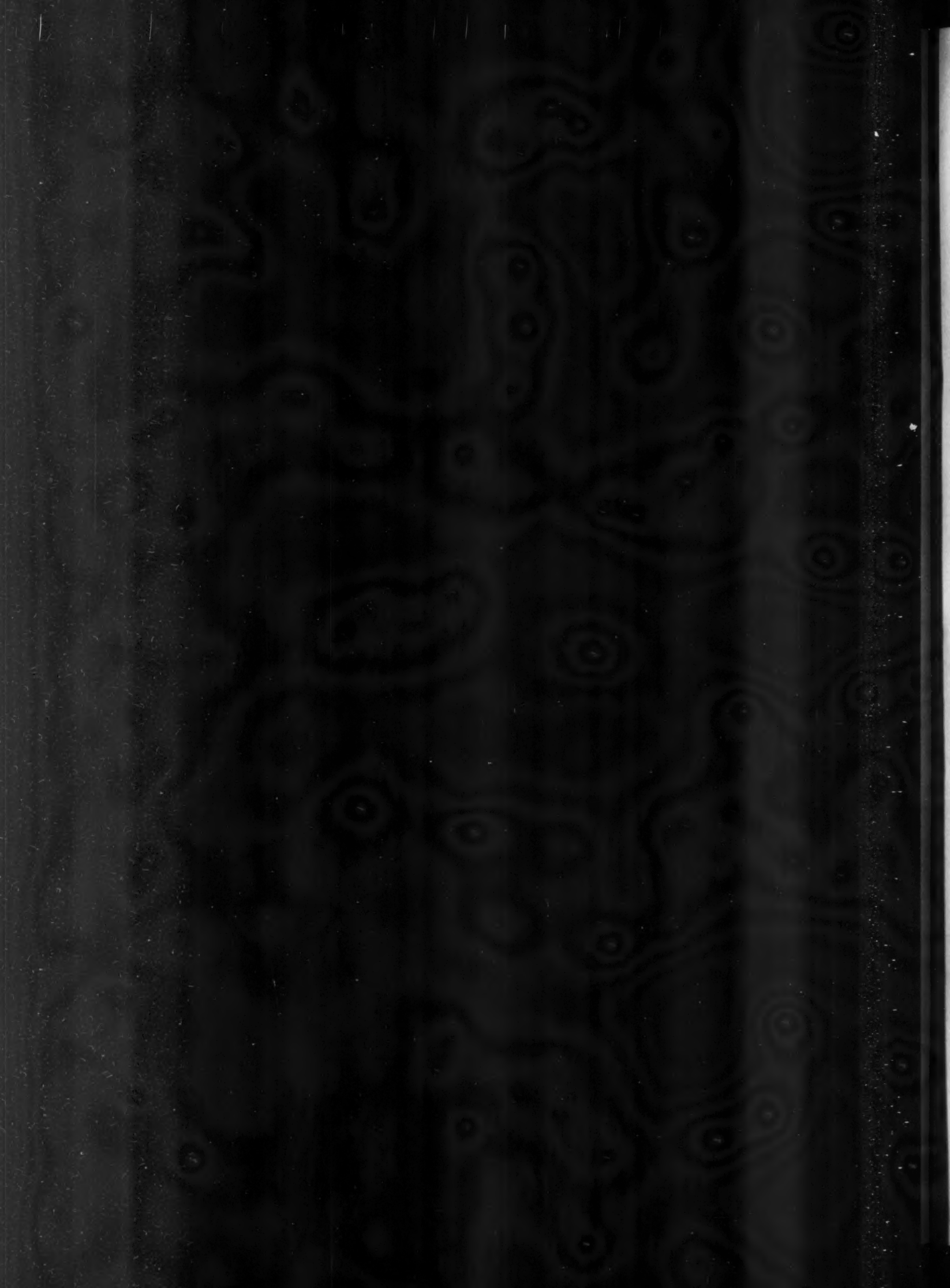
Box U. 148.—Advertiser thanks all applicants and informs them that selected candidates have been written to. U 240

Works Accountant or

SECRETARY WANTED for Works in the London Area (East) employing 12/1500 hands, manufacturing small Electrical Instruments, to take charge under Works Manager, of all Clerical Staff, Costs System, Works Accounts. Experience in cost keeping in engineering works essential. Preference given to man of good education and address. Salary £5/600 per annum.—Write, BOX 179, SELL'S Advertising Offices, Fleet St., E.C. 4. U 250



NOZZLE LOSSES IN COMPOUND TURBINES.

CERTAIN Continental engineers have claimed, that the higher the steam speed the more efficient the turbine. This theory is based on the fact that taking any given nozzle, the higher the velocity of efflux the less proportionately is the energy wasted in friction, a conclusion which is quite in accord with the well established result that in smooth pipes the friction head does not increase quite as fast as the square of the velocity of flow. Nevertheless, the deduction made by the Continental engineers in question does not on a casual survey appear to be supported by practical experience. In a paper published during 1919 in the *Zeitschrift Vereines Deutscher Ingenieure* Dr. R. Flügel suggested that the explanation might be found in the circumstance that a dimensional factor is involved in the resistance to the flow of fluids through similar channels. For example to a first approximation the head dissipated in 100 ft. of water main is inversely proportional to the diameter of the pipe. If in a steam turbine the steam speed be diminished larger nozzles will be required to pass the required quantity of steam, and he suggested that in this increase of dimension was to be found the explanation of the fact that in practice turbines with low steam speeds appear to be quite as efficient as turbines whith high steam speeds. The suggestion is plausible, but it appears to be untenable when the problem is more thoroughly investigated.

By the principle of dynamic similarity established by Stokes in 1850, R the resistance per square centimetre of rubbing surface is given by the relation

$$R = \rho v^2 \phi \left(\frac{\nu}{v\,d}\right)$$

where ϕ denotes some function of the expression in brackets and ρ denotes the density of the fluid in grammes per cubic centimetre, v the velocity of flow in centimetres per second, ν the kinematic viscosity of the fluid and d the diameter or some other typical parameter of the water-way.

The truth of the above deduction from theory is strikingly exemplified by Fig. 1, which is reproduced from a paper by Professor C. H. Lees, F.R.S., published in the Proceedings of the Royal Society for 1914. The diagram shows the results of experiments on pipe friction made at the National Physical Laboratory by Dr. Stanton and Mr. Pannell. One series of experiments were made with air, and the others with water, yet it will be seen that though the one fluid was a liquid and the other a gas the laws governing the flow are identical, and the results for both are remarkably well represented by Professor Lees' formula—

$$R = \rho v^2 \left[0{\cdot}0009 + 0{\cdot}0763 \left(\frac{\nu}{v\,d}\right)^{0{\cdot}35}\right]$$

It will be noted that at low velocities the plotted points fall on an entirely different curve to that which represents them at high velocities of flow. In the former case the flow is linear in character, whilst at higher velocities it is turbulent. There is, it will be seen, a region of transition between the two curves in which observations plot erratically and repeat experiments do not necessarily yield concordant results. In the conditions corresponding to this region the fluid cannot in fact, "quite make up its mind" as to whether to be turbulent or not.

In view of this very striking demonstration of the truth of the law of dynamic similarity we can apply it with confidence to Dr. Flügel's problem. In the case of smooth pipes it is known that for quite a considerable range of conditions the resistance to flow can be represented with reasonable accuracy by the formula—

$$R = \rho v^2 \left[\frac{\nu}{v\,d}\right]^n$$

where n is a small fractional power of the order of 0·1 to 0·2. Let us assume that the resistance of the steam ways in a turbine can be represented by a similar formula. In the case of steam it is better to replace ν by $\frac{\mu}{\rho}$ where μ denotes the viscosity of the fluid as given in collections of physical constants and ρ is the density of the steam. One advantage of this procedure is that μ does not vary with the pressure, but only with the temperature. We can consequently write the term $\frac{\nu}{v\,d}$ as $\frac{\mu d}{\rho v d^2}$

But $\rho v d^2$ is proportional to the mass passed per second. Calling this m we get for the resistance per square centimetre of the wetted surface of the steamways, the expression—

$$R = A \rho v^2 \left[\frac{\mu d}{m}\right]^n$$

where A is a purely numerical coefficient.

Let l be the length of the nozzle and d its diameter or other characteristic dimension. Then the total resistance to flow is proportional to $R\,l\,d$ and the work done per second against this resistance is proportional to $Rlvd$. Since the mass passed per second is proportional to $\rho v d^2$, the energy wasted per unit of mass is—

$$\frac{R\,l\,v\,d}{\rho v d^2} = C_1 \frac{l v d}{\rho v d^2} \cdot \rho v^2 \left[\frac{\mu d}{m}\right]^n$$

$$= C_1 \frac{l}{d} \cdot v^2 \left[\frac{\mu d}{m}\right]^n$$

where C_1 and n are constants to be determined by experiment.

In geometrically similar channels $\frac{l}{d}$ is constant. Hence for such channels the energy dissipated per unit mass passed per second may be written as $\frac{C}{2} \cdot v^2 \cdot \left[\frac{\mu d}{m}\right]^n$.

In the case of a nozzle v denotes the actual velocity attained. Let v^1 represent the velocity theoretically due. Then from the principle of the conservation of energy we have—

$$(v^1)^2 = v^2 + C v^2 \left[\frac{\mu d}{m}\right]^n$$

The nozzle efficiency is equal to $\left(\frac{v}{v^1}\right)^2$ i.e., to

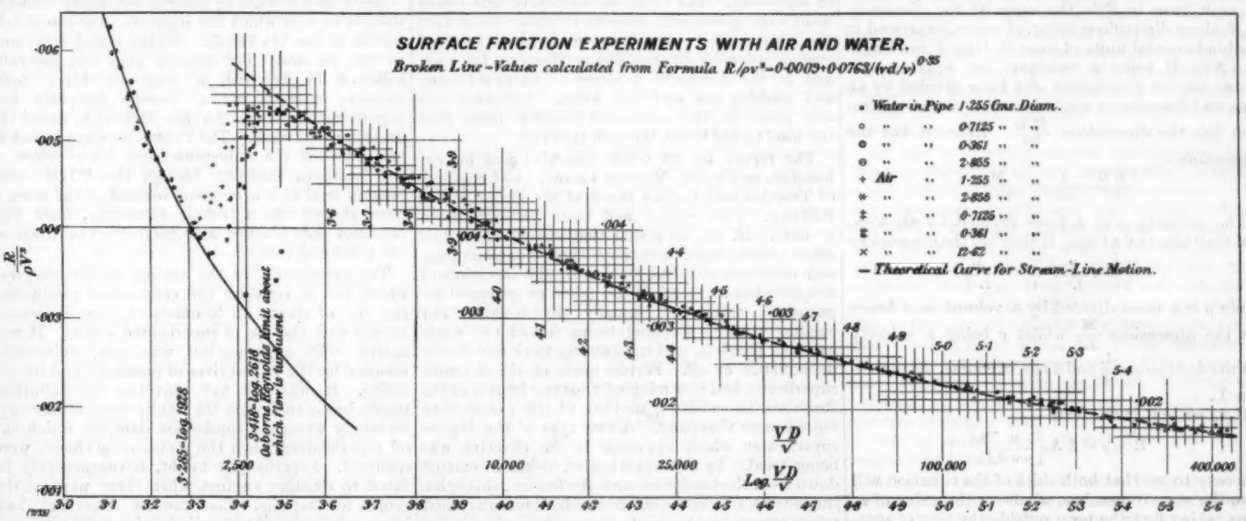
$$\frac{1}{1 + C \cdot \left(\frac{\mu d}{m}\right)^n} = 1 - C \left(\frac{\mu d}{m}\right)^n$$

nearly, the second term in the denominator being always small compared with unity. We thus see that the percentage loss in a nozzle is proportional to $\left(\frac{\mu d}{m}\right)^n$

In a turbine in which the steam speed is high the value of d will be less than in a turbine passing the same mass of steam per second, but having a greater number of stages. Hence if n be, as it is natural to suppose, a positive number the nozzle losses will be less in the high speed turbine and the fact that this is not supported by experience must be sought elsewhere than in the dimensional factor suggested by Dr. Flügel.

Actual experience may be explained in part by the fact that the more stages in the turbine the higher the reheat factor; but calculation shows that the gain due to this circumstance is very small. The slow speed turbine has, however, another advantage in that the losses by disc friction and the like in a slow speed turbine of given output are smaller proportionately than in a machine with high blade speeds. In the foregoing the value of n has been left indeterminate. In the case of parallel pipes it is known to be a small fraction, but its value for nozzles does not seem to have been investigated. Such a research would be of interest, and could be carried out with comparatively simple apparatus using water as the fluid. The viscosity of water is about four times as great at 0° C. as it is at 50° C., so that a fair range of values would be readily available and from the principle of dynamic similarity, the coefficients found for water would also apply to steam.*

As has been stated above the theory of dynamic similarity shows us that when any viscous fluid flows through a channel the frictional resistance per square centimetre of wetted surface must be expressible in the form $\rho v^2 \phi \left(\frac{\nu}{v\,d}\right)$ where ϕ denotes some function of the quantity in brackets. The



* This conclusion is perfectly sound, provided that the only physical properties of the fluid, involved in the problem, are its viscosity and its density. The experiments of Stanton and Pannell plotted in Fig. 1, prove that this assumption is correct for the range covered in their investigations. It seems improbable, however, that it holds indefinitely. All theories as to pipe friction involve the assumption that the layer of molecules which touch the pipe will fix themselves there, and experiment shows that this is true under ordinary conditions, but under excessively high rates of flow it seems likely that this rule may fail to hold, and in that case the analogy between water and steam may break down. In a note presented to the Physical Society in 1919, H. M. Martin suggested that here was to be found the distinction between a good and a bad lubricant. Under very high rates of shear the bond between the molecules of a bad lubricant and the adjacent solid surface gives way, whilst with a good lubricant it is maintained.

argument by which this is proved is well known to physicists, but is less familiar to engineers than it should be, so that it may be of service to some readers to set it forth here. Consider a channel of stated form; but which may be made in different sizes, all, however, being geometrically similar. This change of scale may affect the resistance which it offers to a fluid passing through it. Hence this resistance to flow may vary as some function of d where d denotes the diameter of the waterway or any other characteristic dimension. Similarly the resistance to flow may vary with the velocity of the fluid v, its density ρ, and its viscosity μ. So long as the form of the channel is unaltered there is no other variable entering into the problem. Hence if R denote the frictional resistance per unit of wetted surface we may write—

$$R = F(d\,\mu\,\rho\,v).$$

It is convenient in discussions involving first principles to keep to the C.G.S. system of units. Hence we shall express R in dynes per square centimetre,* ρ in grammes per cubic centimetre, d in centimetres and v in centimetres per second. Now F can be regarded as the sum of a number of terms of the form $A_n \cdot \mu^x \rho^y v^z d^n$ where A denotes a purely numerical quantity, and the indices $x\ y\ z$ and n are so related that the dimension of each term in F is the same as the dimension of R, these dimensions being, of course, expressed in the fundamental units of mass M, time T and length L. Now R being a resistance per square centimetre has the dimensions of a force divided by an area and force being equivalent to a mass acceleration has the dimensions $\frac{M\,L}{T^2}$. Hence R has the dimensions—

$$\frac{M\,L}{T^2} \cdot \frac{1}{L^2} = \frac{M}{T^2\,L}$$

The viscosity μ is a force divided by an area, and multiplied by a time. It thus has the dimensions

$$\frac{M\,L}{T^2} \cdot \frac{1}{L^2} \cdot \frac{T}{1} = \frac{M}{L\,T}$$

Again ρ is a mass divided by a volume and hence has the dimensions $\frac{M}{L^3}$ whilst v being a velocity has the dimensions $\frac{L}{T}$ and d has, of course, the dimension L.

If we write R in the form—

$$R = \rho\,v^2\,\Sigma\,A_n\left[\frac{\mu}{\rho\,v\,d}\right]^n$$

it is easy to see that both sides of the equation will have the same dimensions whatever the value of n. Thus taking first the term outside the sign of summation, viz. $\rho\,v^2$, its dimensions are

$$\frac{M}{L^3} \cdot \frac{L^2}{T^2} = \frac{M}{L\,T^2}.$$

or the same as those of R. Hence the terms under the sign of summation must be of zero dimensions and this is easily seen to be the case. For on substituting the dimensions already given for μ, ρ, v and d we get

$$\frac{M}{L\,T} \cdot \frac{L^3}{M} \cdot \frac{T}{L} \cdot \frac{1}{L}.$$

in which the terms in numerator and denominator cancel each other out. The values of A_n and n have, of course, to be determined by experiment.

THE INTERNATIONAL RAILWAY CONGRESS AT ROME.

(*Continued from page 578.*)

THE PRODUCTION OF STEAM ON LOCOMOTIVES.

For Section II, which considered, among other subjects, the Economic Production and Use of Steam on Locomotives, Mr. G. J. Churchward prepared, in 1914, a short report showing the position at that time as regards superheating. A small supplementary report compiled last year brings the actual statistics up to date, but otherwise does not affect the earlier conclusions. These were to the effect that the use of superheating was gradually extending, though the progress made where coal and labour were cheap was not so great as elsewhere. The working economy was about 12½ per cent. The superheating of compounds did not make much progress, while doubt existed as to fitting superheaters to locomotives working stopping trains. The usual superheat was 200 deg. to 250 deg. F. The Great Western Railway used rather less. The cost of upkeep of engines with superheaters was not appreciably greater than of other engines. For lubrication, mineral oil was used having a flash-point of about 575 deg. F., or about 50 deg. F. higher than that used for non-superheater engines. Pyrometers were not very reliable. Trouble was experienced with deposit on the valves due to carbonised oil. Air and relief valves were necessary. Dampers in the smoke-box were being discarded, and the practice of fitting old boilers with superheaters was extending. For glands, instead of the usual white metal packing ring, the Great Western Railway, with moderate superheat, employed flexible rope packing prepared with a metallic solution.

On the question of feed-water heating, Mr. Churchward reported that the use of the exhaust injector was extending, and feed heating systems were being tried experimentally. The advantages were worth obtaining. On the Great Western they amounted to 8 per cent. economy of fuel with a very considerable improvement in the life and upkeep of the boiler. The third sub-section of this report dealt with special arrangements in which connection Mr. Churchward referred to the internal top-feed system adopted by the Great Western Railway, and to the increasing practice of water-softening and washing out with hot water. Reference was also made to the automatic variable blast pipe top used on the Great Western Railway.

The report for all other countries was an exhaustive one by M. Maurice Lacoin, chief engineer of Traction and Rolling Stock of the Paris-Orleans Railway. This report had been brought down to date. M. Lacoin stated that superheating had made more rapid headway than compounding, and developments had tended in the direction of simplification. It might be taken as universal for passenger work and usually for freight. For engines working stopping trains it had not made so much progress, and in shunting work practically no advance at all. Former users of the Schmidt superheater had now adopted the type known as the Robinson superheater, or that of the Locomotive Superheater Company. A new type of the Mestre superheater which appeared to be effective was being tried. In this superheater, steam is carried down from the header towards the fire-box through a single tube, to a spear end from which four flattened tubes return to the smoke box, where they unite in a union and are connected by a single pipe to the high degree header. The two-cylinder superheater locomotive was supplanting the four-cylinder compound, but it was probable both types would continue side by side for some time. In local service superheating offered economy especially if dampers were discarded. The additional weight due to the superheater was about 3 per cent. or 4 per cent. of the engine and the extra power resulting 10 per cent. to 20 per cent. The economy ranged between 10 per cent. and 15 per cent. The extra cost of the appliance seemed to be 4 per cent. to 5 per cent. of the cost of the engine.

Oils with a flash point of about 662° Fahr. were used. Their price was higher, and more was consumed than in saturated steam engines. Piston and valve rod packing tended towards simplification. Most of the railways retained dampers in the smoke box, though they had been abolished by some lines in Italy and France. It was found advisable in cleaning the boiler tubes to scrape the tube ends periodically. Pyrometers generally were unreliable, though pyrometers using saturated steam pressure had given some satisfaction. The thermo-electric type had not been in use long enough for a decision to be arrived at as to its reliability. It was not considered that piston valves gave any serious trouble from becoming coated with deposit. The area of relief valves had been increased. They were now one-sixth to one-twelfth of the cylinder diameter; in one case as much as one-quarter. Air inlet valves were also generally used and the by-pass was also commonly adopted, the lifting valve being preferred to the tumbler cock. Certain railways used an arrangement which combined the functions of both these.

As regards feed-water heating the Knorr and Caille-Potonié systems, both resulted in economy, but offered certain difficulties in working owing to the rapid scaling of the tubes. Railways were not yet satisfied as to the advantages gained. The Worthington system was being tried on several railways and the Davies and Metcalfe exhaust steam injector was being experimented with in France. The use of water-tube boilers had made no progress since 1910. In connection with the delivery of feed, this was often now delivered into the steam space, but various companies had special arrangements of boxes and baffles at the end of the feed pipe to ensure rapid heating and precipitation of scale, &c. Passing the feed pipes through the boiler was usually avoided because of trouble with scaling. The Gölsdörf system of delivering the feed into a submerged box did not appear to present definite advantages. Other methods of the kind had been tried, but without conclusive result. Hot water washing out was adopted in some cases, but without, if possible, the use of the more expensive plants. With this the engines could be kept longer at work, but the advantages to the boiler were difficult to estimate.

Brick arches were in general use, many railways using a type in which the supports were completely buried in the brickwork. Arches lasted from four to ten months. The lagging used was generally asbestos blocks with a magnesia base. Some railways were trying a vacuum indicator and registering apparatus for the firebox, to assist the fireman in his work. The French railways generally had adopted the adjustable cone blast orifice of the Northern Railway, though the P.L.M. were making trial of a type using instead of the cone, a piece shaped like a trefoil. Generally, blast pipe tops had been lowered with good effect on draft on the grate and tubes.

The conclusions of the section of the congress which sat to consider the economical production and use of steam on locomotives were concerned largely with the use of superheated steam. It was agreed that superheating was now universally adopted for the locomotives of passenger and freight trains. It was not yet universal for suburban traffic, but in such work the results were satisfactory, especially when the smoke-box dampers which cut off superheating when the regulator is closed, were removed. Superheaters might, advantageously be fitted to existing engines when these were in the shops for repairs. The use of superheat had increased the use of two-cylinder simple locomotives. For powerful engines the opinions of railway engineers were divided between the merits of the two-cylinder simple engine with superheat, the four-cylinder compound with superheat, and the three or four-cylinder simple engine with superheat, The fuel economy obtained by using superheat in the case of simple engines averaged, under ordinary working conditions, from 10 per cent. to 20 per cent. The saving, however, was very variable, depending both on the nature of the work done and the condition in which the engine was maintained. It was necessary to adopt a higher standard of maintenance with superheater engines than when saturated steam was employed.

A progressive simplification was noted in the details of superheater engines, the special arrangements originally adopted for valves and pistons having been found unnecessary, and practice approximating more and more to that of saturated steam engines. On new locomotives, piston valves were exclusively used for the high-pressure cylinders and packings with sliding joints and external cooling for rods exposed to superheated steam. The area of the cylinder relief valves had also been increased. These were the only special arrangements, the necessity for which was universally recognised. The instructions given to drivers as to the management of their engines also tended to become more simple as experience increased. No progress had been made with either the introduction of Corliss, or similar valves, or with the uniflow principle in connection with locomotives. Some railway companies used, at the same time, both inlet air valves and a by-pass to avoid the

* One million dynes per sq. cm. is equivalent to 1 bar or 14·50 lb per sq. in.

formation of a vacuum in the cylinder when the engine is running with steam shut off, but the value of this double provision did not appear to have been fully established.

With regard to feed-water heating on locomotives, it was considered that the results which had been obtained with exhaust steam ejectors justified the extension of the use of such devices. No progress had been made with the application of water-tube boilers to locomotives, and the experiments so far carried out had not enabled any definite conclusions to be arrived at. In any case the possible advantages appeared to be small. The use of hot water for washing out locomotive boilers was beneficial, particularly when the time available was short. Washing-out plants with auxiliary boiler and fixed water and steam piping, allowing of the saving of the water and heat from incoming locomotives, were adopted with advantage in particluar cases, especially where water was scarce, but their cost and complication militated against their extensive use on systems where the engines had fixed bookings. The use of firebrick arches in locomotive fire-boxes had become general as they resulted in improved combustion.

NOTE ON OIL FUEL.

The note prepared by Sir Henry Fowler, K.B.E., chief mechanical engineer of the Midland Railway, on the utility of studying the question of liquid fuel for locomotives, did not suggest that there would be much object in the congress taking this matter up. Sir Henry considered that the use of liquid fuel was very local and mostly confined to the vicinity of oil fields. Only seven of the reporting lines used it at all extensively. As generally applied it required no great alteration to the standard fire-box and the cost of fitting was not high. It appeared to present no special advantage for any particular type of locomotive. In some cases it was used during summer months to avoid risk of forest fires. The use of superheated steam had offset the advantages of its employment on gradients, as supplemental to coal. The burners were commonly of two types. In one, oil flowed through a narrow horizontal slot, and steam issued from a corresponding slot below; in the other, the oil issued from a circular orifice, the steam being supplied through a central cone. The first type was commonly placed in the front of the box, and the second in the back. A pressure system was also being tried, but there was trouble from the small apertures in the atomiser becoming clogged. Steam was used in all cases for atomising. The firebrick lining of the box and ash pan had to be well maintained. Good ordinary firebricks were satisfactory. The oil-supply was commonly heated by steam coil to about 100 deg. F. Tubes sometimes required cleaning when on the road. This was done by sanding. It was generally considered that the high temperatures increased fire-box and boiler troubles. The question of smoke was mainly one of training. There were no mechanical difficulties in the adoption of oil fuel, the question being one of the relative supply and cost of oil and coal. Oil was easy to handle and store, and for equal calorific value occupied about half the space and was about half the weight. Greater steam production was possible than with coal. The possibilities of the internal combustion locomotive, Sir Henry thought to be of more interest to the congress than further study of oil fuel.

The conclusions of the congress with regard to Sir Henry Fowler's note were that there were no mechanical difficulties in the adoption and use of liquid fuel on locomotives. The question of the cost both of the fuel and of maintenance prohibited its use at present, except in certain localities, and these were so restricted that the subject was not considered urgent enough for immediate discussion. It might, however, be taken up later if prices became more favourable. The use of liquid fuel with internal-combustion engines on locomotives was, however, of more general interest and might be considered later.

PASSENGER COACHES.

The subject of passenger coaches as affected by the requirements of safety and comfort was discussed by Section II. Two reports were submitted regarding passenger coaches in America. Both were models of conciseness, and contrasted greatly with some of the lengthy contributions presented to the congress. Both took the form of a series of questions with the reporter's summary of replies received. The first, which was the more brief of the two, was by Mr. B. F. Bush, and was prepared in time for the 1915 Congress. It was unillustrated. The second was supplementary, emphasising many of the points brought out by Mr. Bush, and bringing the subject up to date. Naturally, on account of her relatively late entry into the war America's railway development was not suspended so early as in other countries; but Mr. Tollerton's report for the main part chiefly serves to follow up and confirm tendencies which were more or less only suggestive at the time of Mr. Bush's compilation. Mr. Tollerton, who is general mechanical superintendent of the Chicago Rock Island and Pacific railroad, supplemented his report with numerous photographs of cars and interiors, and drawings of main features.

The main points of both reports may be combined. Among these were that all steel construction was adopted in deference to public opinion. Wood was practically eliminated with the object of making the cars fireproof. Bogie stock was universal, with enclosed vestibules as a rule. Fish-bellied centre longitudinals were usual. The vestibules were usually strengthened in order to make them as far as possible collision-proof. Four and six-wheeled bogies were both used, the six-wheeled bogie being used for heavy cars. Bogie frames were often steel castings in one piece. Generally speaking side doors were not used. Rolled steel wheels were employed in modern stock. High speed brakes were adopted, and every care was taken to prevent the brake rigging from rattling, in some cases parts being encased with wood for this purpose. Friction draught gear was the general standard, with a central buffer and coupling, provided with spring centring control. Draw-gear was non-continuous.

Car bodies were of steel with steel framing, practically all recent construction was of this material. Between the false bottom and the floor padding was adopted to deaden the sound. A cement composition was sometimes laid on a floor of incombustible material, or the steel underframe. Double windows were provided in the cold countries, and were also used on trains through the salt lands. Windows could be raised 18 in. to 22 in. The walkover seat was general for day coaches. The general arrangement of sleeping car in use in America being probably familiar to our readers we will omit this section of the report. Great care was taken in providing a good drinking water supply in all coaches, and many steps had been taken in recent years to improve this service, such as separating the ice from the filtered water, frequently cleaning out the tanks, and so on. Hot water was available in lavatories. Practically all modern carriages were electrically lighted, either by axle-driven units, or by head-end units in the baggage car or on the locomotive. Steam heating was almost universally adopted. As regards ventilation this was provided by the side lights, and by ventilators in the clerestory. A form of ventilator was being adopted in which air was taken in by an intake trunk and led down to either side of the car, being passed over radiator coils under the seats before being admitted to the interior of the car. The clerestory roof had in many cases given place to the semi-elliptical or turtle-back roof, as regards exterior outline, the clerestory feature being retained in the interior.

The question of the design of passenger carriages, as regards Great Britain, India, Australasia and South Africa, was in the hands of Mr. R. W. Reid, of the Midland Railway. Mr. Reid's report was a lengthy one and very fully illustrated. It showed that all stock had greatly improved in recent years. The corridor bogie vehicle was in general use for fast trains, and bogie compartment stock for suburban work. Dining cars and compartment sleeping cars were used on many lines. For the latter an extra charge was made. Four- and six-wheeled stock was being eliminated.

Lighter stock, when possible, was attached at the rear of bogie stock. Bodies were of oak and teak, with joints strengthened by knees. Fireproofed timber had not been altogether satisfactory. All-steel coaches were used on the underground and local services. The usual compartment vehicle, however, did not lend itself well to this type of construction. The tendency of steel panelling to corrode had to be considered. The semi-elliptical roof was becoming standard. It was thought better to ensure safety in working than to make stock collision proof. The four-wheeled bogie was general, the six-wheeled being less common. On the Great Northern Railway articulated vehicles were used by which three instead of four bogies were employed for two bodies. The all-steel underframe was universal. On account of the tendency in collision for the bogie to become sheared away from the underframe, the king pin was being replaced by a steel casting and centre-pin of large diameter. Double case buffers were now employed as extra security in case of collision. On some through stock Buckeye couplers were used. The steel disc wheel had now largely replaced the wooden wheel. The rapid acting Westinghouse brake was not used except on electrified lines. Accelerating valves were fitted to the vacuum brake.

Door locks were commonly of the double-acting type. An alarm was provided acting on the train pipe. As regards ventilation, torpedo ventilators were common, capable of extracting 30 cub. ft. to 40 cub. ft. of air per minute when travelling at a speed of 50 m.p.h. A glass vertical adjustable louvre ventilator was often fitted in dining and other cars, but was too expensive for use on ordinary stock. Interior carving and decoration had given place to plain moulding and plain panelling. Basins and closets were usually in the same compartment. Floors and corners in such compartments were rounded off.

As regards lighting, electric lighting was being fitted to practically all new express stock, although it still offered a wide field for improvement. For suburban work incandescent gas lighting was still preferred. Through control of gas lighting had been adopted in cases with good results. The uniform opinion was that electricity was more expensive than gas, both in first cost and maintenance, and the risk of failure with it was greater. The actual cost of lighting was greater than with gas. On the other hand, the public favoured it on account of the reduced risk. When gas was used, safety valves were employed. Heating was universal in new stock either on the high or low pressure systems; from 1·8 sq. in. to 2·75 sq. in. of heating surface was allowed for 1 cub. ft. of compartment space.

In India bogie coaches were being generally adopted, in some cases all-steel coaches being employed. The corridor coach was not general. Lavatory accommodation was provided for all classes. Electricity was used for lighting, and for the fans, though gas lighting was still used on most stock. In South Africa bogie stock was general, with steel underframes and wooden bodies. Lighting by electricity was universal; there were no gas-lighting plants in the country. In New South Wales the stock was practically all of the bogie type. Side corridor compartment carriages were used for express service, though in some cases compartments were provided with lavatories and no corridors. Sleeping berths were arranged in compartments, across the car with side corridor. Oil gas lighting was common, but electricity was extending. No heating system was employed. The quick-acting Westinghouse brake was used. In New Zealand, bogie vestibule coaches were used, with end doors only, and central lavatory. Sleeping cars were of the compartment type. The underframes were of steel and bodies of native woods, usually a dark and light coloured durable pine. Central buffers and drawgear were the standard, while continuous heating and the quick-acting Westinghouse brake were fitted. Gas was most used for lighting, except for sleeping cars in which electricity was employed.

Points to consider in design were improved construction to withstand shock and telescoping and reduce the risk of fire, means for reducing noise, the comparative weight of steel and timber vehicles, relative merits of gas and electric lighting, and the advisability of adopting quick-acting forms of brake. Fireproofing of timber and other matters were also worth continued attention.

The report by M. E. Biard, of the Eastern Railway of France, on passenger carriage design for other than English and Spanish speaking countries was a lengthy one which treated the matter in hand in a rather unusual way. The report was unillustrated, and scarcely referred to the practice of particular railways, but occasionally to countries. The whole took the form of a general summary. M. Biard pointed out that the set-back resulting from the war had caused a complete suspension of new designing which was only now being undertaken in a few instances. The new post-war stock built had so far nearly all been to pre-war designs. Safety was of prime importance and expenditure was unavoidable to attain it. Comfort, on the other hand, was a relative matter. As regards safety, carriages were now built with a view to withstanding shocks better, and there was a tendency for all elements of the construction to be strengthened. Comfort at high speeds required improved suspension, while greater care was taken in the actual building of the stock. Bogie stock was becoming more general as elsewhere. Steel was taking the place of wood, except for bodies with side doors. All-steel construction was hardly used except for some suburban services.

In addition to the greater comfort provided by the use of easy-riding bogie stock, more tangible comforts were provided in the way of greater space per seat, lavatory accommodation and other conveniences, such as means of access to dining cars, &c. Four and six-wheeled vehicles were being discontinued, though those still built were of longer wheel-base and heavier construction than formerly, and that stock could be used on fast trains. Bogie stock, however, cost more, and cost of upkeep was greater than for other stock. Carriages with separate compartments and without corridors were not often built except for local services. The corridor was becoming common, and, for long-distance trains, the through type of corridor coach, with compartments. End vestibules afforded some degree of protection to passengers in the event of collision. Some systems combined the through corridor with side doors. Generally improvement in comfort was to be found in all classes, but relatively it had been more marked in the third class. Chilled iron wheels had been discontinued; disc wheel centres were preferred to spokes, being quieter and causing less dust. Couplings had been strengthened. Side play was commonly allowed to the drawbar hook, while compensating levers were used between buffers. Four-wheeled bogies were most usual, with a wheelbase of about 8 ft., but in some cases as much as 9 ft. 10½ in. With six-wheeled bogies the wheelbase was as much as 12 ft. 1⅝ in. in the case of wagons-lits.

The use of the clerestory roof was not very common, the arch roof being more usual, the interior often being treated as two arches, one over the corridor and one over the compartment. This, however, lessened the cubic feet of air space per passenger. Double roofs were not employed, though generally roofs were arranged with outer covering and lining. Flooring was often double, or even treble, with the intervening space packed. This practice depended on the climatic conditions. Automatic door locks and latches were being introduced with safety catches. Lavatories showed a tendency to conform to the improved sanitary arrangements now considered desirable. Wood work was being eliminated, corners rounded, and use made of enamelled surfaces. As regards sleeping cars, practice differed widely from the first-class only in France, to third-class sleepers in Sweden and Russia. There were many special types of convertible compartments.

As regards brakes, the Hardy vacuum and Westinghouse were most common. Alarm was by air signal as a rule. In compartment coaches, glass panels were compulsory in some countries, between compartments. Lighting had been much improved; gas with mantles was common, but electric lighting was also being applied. Both systems appeared to be capable of improvement from the point of view of safety. Heating was most commonly by steam either in connection with radiators under the seats, and/or, foot-warmers in the floor. As regards make-up of stock, on some lines carriages of less than 16 tons tare were not allowed in front of bogie stock. In other cases limits of wheelbase or weight were laid down for stock for fast trains.

The report on passenger rolling-stock, for Spanish-speaking countries, was submitted by M. F. de Vargas, of the Northern of Spain Railway Company. This report was also one of those originally drawn up in 1914, but during the intervening years little change of practice has been brought about. In recent years the great tendency had been, M. de Vargas stated, towards increased deadweight per seat, on account of the improved standard of comfort now given to passengers. This had involved the use of heavier and more powerful locomotives. In Spain restaurant and sleeping cars were provided usually by the International Sleeping Car Company. In general, the make-up of the trains had become more elaborate, improved methods of construction had been adopted in carriages, more room was allowed, corridors fitted, lavatories provided, accessories such as lighting and heating had been improved, and so on. Many improvements had been adopted tending to easy and steady running. The use of bogie vehicles for new construction was becoming universal. Practically all companies reported that this heavier stock was adopted mainly to provide extra comfort.

In Spanish-speaking South America the American form of construction was employed. The Spanish railways adopted the European system. In some stock of the latter systems composite steel and wooden underframes were used, but the tendency was towards all steel frames and all steel bogies, though some systems adhered to composite bogies. The bogie bolster and spring plank were sometimes of wood. Axles and axle-boxes conformed to accepted practice. With regard to drawgear and buffers the latter were commonly independent, though sometimes combined by links and levers. Most of the drawgear in South America was continuous. On the Argentine State lines the Gould coupler was employed. In Spain, drawgear was continuous for four-wheeled vehicles, and independent for bogie stock. The screw coupling was used. Body work was of wood, no all-steel coaches as yet being employed. Windows were often provided with venetian screens, blinds, &c. Spanish railways did not run sleeping car services, these being in the hands of the International Company. There were two exceptions to this rule, and these companies had a certain number of composite cars fitted with a number of compartment berths, and also with arm-chairs convertible into berths at night. In South America the sleeping cars were, as a rule, on the European compartment system. Lavatory accommodation had been considerably improved. In America it was usual to separate the basin and closet compartments, but in Europe one compartment was used for both. Generally speaking, hot water was not furnished, only two Spanish companies making provision for this. The brakes used, except on the Argentine State, which used the Westinghouse rapid action, were of the vacuum type, and included the Smith-Hardy, Clayton and other systems; rapid action valves were not used as a rule. On Spanish railways an alarm was provided, but not on the South American lines. Lighting was by acetylene, compressed coal gas, Pintsch gas, and electric lights. Olive oil was also used. Electric lighting was taking the place of other systems. Stone's system and the Vicarino system were the most common; others were being tried. Heating was in use on the Argentine State and on several Spanish lines, the systems being the Heintz, Laycock and Westinghouse.

It was usual to avoid double heading, if possible, though this was permitted by regulations. In Spain, regulations prohibited placing a heavy vehicle behind a lighter if the weight of one exceeded the other by one-third. Generally the bogie vehicle was becoming the standard. Framework, &c., was being strengthened. All steel construction had not yet been introduced in these countries. Improvements had become necessary in buffing and drawgear. Suspension, especially in four-wheeled stock, required improving. Braking was becoming of more importance. All the improvements had tended to increased weight per passenger and had added to the cost of transport. Supplementary charges might quite well be justified to meet this to some extent.

The conclusions of the section which considered the above reports were that the bogie type of carriage was universal in America, and was tending to become general for express and long distance trains in all countries. The four-wheel bogie was generally adequate, but the six-wheel bogie was necessary where the weight carried was very great. In England experiments had been made with articulated trains, one bogie being common to two carriages, but this practice was not generally applied to whole trains. In the United States vestibule coaches with through connections were exclusively used, and there was a tendency for this system to be adopted for long-distance trains in other countries, although on many trains coaches with side doors and corridors extending throughout the trains were used. The construction of carriages entirely, or almost entirely, of metal had developed rapidly in North America and was generally adopted there, as it was considered conducive to safety in case of accident. In Europe metal construction had not been used to any appreciable extent except in the case of electrified lines, although certain systems had it under consideration. It came out in the discussion that the principal reasons why all-steel cars had been adopted on the New York Metropolitan Railway were to attain fireproofness and to facilitate the fitting of the electric equipment. In England it was considered better to look after safety by the improvement of signals than to build carriages specially to withstand accidents. In the suburban services the weight of vehicles having a steel underframe and wooden body amounted to 600 lb. per seat, whereas all-steel vehicles worked out to 900 lb. per seat, and even 1,400 lb. per seat if they were to be specially strong to resist collisions. On the London Metropolitan Railway all steel coaches were colder, noisier and less neat than those with wooden bodies, and were also more expensive.

A suggestion that alarm knobs should be fitted lower down and at the four corners of each carriage was negatived. This had been tried and abandoned in France, and Colonel Pringle concurred in its inadvisability. It had not been found that the frequency of criminal attacks in trains was influenced by the type of carriage employed. For the lighting of railway carriages electricity was tending to replace gas completely, as the latter was held to cause or increase danger from fire in case of collision. Heating trains by means of steam from the locomotive was becoming more and more widespread, and improvements had been introduced with the idea of ensuring the last carriage being adequately warmed, and of regulating the heat in the various compartments. The continuous quick-acting brake was employed on nearly all railway systems, and experiments had been carried out with a view to increasing the rapidity and effectiveness of braking long and heavy trains running at high speeds.

The Congress was of opinion that safety of running might be considerd as ensured so long as each of the separate vehicles was capable by reason of its wheel base and axle loading of travelling at the maximum speed of the train. For this reason nearly all companies insisted on either a minimum wheel base or a minimum weight for all vehicles to be made up into fast trains. Some regulations went further and required the grouping of carriages which did not conform to both these conditions, in a certain order or in a certain position in the train. Other rules had been laid down regarding the use of buffer carriages in front of and at the back of the trains, and as to the maximum number of carriages or axles per train according to the speed and power of the engine. It was desirable that all improvements should be adopted consistent with the economic position of the various railway undertakings.

Locomotive Cab Signals.

There were only two reports on the question of locomotive cab signals, which was discussed by Section III of the Congress, and these constitute practically one presentation of subject. A third report was sent in by Sig. F. Villa, of the Italian State Railways, but too late to be prepared for the Congress, though M. Verdeyen, the special reporter, for this question, referred to it in his summary. The other two reports were respectively by M. F.

Maison, Inspector General of Mines, France, and M. J. Verdeyen, of the Belgian State Railways. M. Maison's report brought the subject for France down to 1914. The report by M. Verdeyen continued it to date, and formed mainly a corrective to M. Maison's contribution, recording as it did the many changes made since 1914. We propose to deal with both reports together, as it is useless going into much detail on matters on which a longer experience has put an altered complexion. The French railways have been compelled to take up this matter by repeated action on the part of the Minister of Public Works, whose attitude has been for a long period in favour of cab signals, giving at least indications of distant signals, though allowing of certain intermediate stages of development. The large railways had now practically all adopted one system or another, only arrived at after a great deal of experimental work.

A good part of M. Maison's report was taken up with descriptions of apparatus still under trial in 1914, but which, as M. Verdeyen points out, have now been discarded. The Northern Railway long ago adopted a ramp or crocodile system giving an audible signal in the cab in connection with the distant signal only, when at danger. The ramp was placed centrally in the track and about 100 yards ahead of its signal. In single line working the ramp was arranged with a tumbler which the brush could trip in the direction of travel, so that current was passed only when travelling in the proper direction. To get over the trouble with ice the ramps were supplied with paraffin from a felt pad. The brush had been improved by making it of steel instead of bronze. Other systems, such as the Eastern, the P.L.M., the Orleans and the State Railways had adopted modified forms of crocodile or ramps. The State railways experimented with a wireless apparatus for some time, but had abandoned it for the sake of uniformity. M. Verdeyen's report adds a description of the Z.S. type of apparatus used on the Alsace-Lorraine system.

Cab signalling as adopted in France was not intended to take the place of fixed track signals, or to constitute a new system of signalling, but only to act as an additional safeguard, and to make it easier to distinguish signals already in use. As any such system was liable to fail at times, if it took the place of track signals it would constitute a source of danger. It was accepted that distant signals should be repeated. Although it was at one time held that giving line clear indications would lessen the alertness of the driver, it now seemed to be accepted that both danger and line clear indications were advisable, but should be easily recognisable one from the other. This change had been due to the risk that no indication might be taken by the driver to mean all clear when really the appliance was out of order. The automatic stop had been repeatedly condemned in France. If absolutely in action, it was liable to be dangerous, and if under the control of the driver it merely amounted to a warning signal. The better plan seemed to be to keep the apparatus as simple as possible, and not to interfere with the freedom of the driver, relying still in the first place on his vigilance and action. In France it was accepted that the cab signal should be audible and, if possible, loud enough if the signal was at danger for the warning to be heard by the train crew as well as the engine crew. This latter object had not been achieved, though in one instance a siren had been adopted which caused a considerable nuisance to neighbours to the railway and had therefore to be discontinued. The signal now was usually a deep toned whistle quite distinct from the engine whistle.

A visible signal tended to take the driver's attention from the road. However, Sig. Villa's report favoured, it seemed, a visible signal in order to make the indication as complete as possible, and the ultimate solution might be a combination of the two. Perfection had not yet been attained. At the same time as development proceeded with cab signalling every effort should be made to make the track signals as perfect as possible, better regard being paid to their position and character. It was desirable that all signals received by the cab apparatus should be recorded on the speed recorder diagram with which all French locomotives were now fitted. The driver should be compelled to make some small movement in connection with the warning given, to ensure his attention being called to it. The ramp or crocodile should be placed at the signal and not ahead of it, for in the latter case it was possible after receiving line clear for the signal to be placed at danger without the driver becoming aware of this fact. The reports concluded with descriptions of the speed indicators and recorders in use in France, that most generally adopted being apparently the Flaman type.

During the discussion on Cab Signalling, Colonel J. W. Pringle, of the Ministry of Transport, of Great Britain, mentioned that he had presided in England over a Commission charged with examining this subject as regards the United Kingdom, and this Commission had estimated that of the serious accidents happening in England during the previous ten years, more than one-third would have been avoided by the repetition of distant signals and more than one-sixth by a repetition of stopping signals. He therefore thought that the repetition of warning signals and certain stopping signals was desirable on double track lines in England. On single tracks, existing methods were adequate. M. Duchatel, of the Eastern Railway of France, considered it by no means proved that the repetition of signals in the cabs of locomotives was conducive to greater safety. The psychological factor had to be taken into account, and was it likely that a driver would observe the road signals so carefully if he relied on their indications being repeated in the cab? This point was very prominent in the discussion. Sir Henry Fowler asked for figures as to the percentage of failures of the cab signals used in France, and being informed that these were of the order of 2 per cent., he remarked that in such a case, he considered them highly dangerous devices. The decisions arrived at by the Congress were that matters concerning cab signalling were still in an experimental state, and precise conclusions could, therefore, not be drawn. The results of the experiments might well be considered at a later Congress.

It was declared that the use of speed indicating and recording apparatus was well developed on the Continent. The use of such apparatus generally permitted the railway companies to dispense with the employment of fixed apparatus for measuring speed, but did not avoid the necessity for such methods at particular places where speed had to be measured accurately. Speed indicating apparatus was only used to check the speed of trains, and was not employed at all either in England or America.

Special Steels.

The report on special steels for track work, which subject was also considered by Section I, was, so far as America was concerned, in the hands of Mr. W. C. Cushing, engineer of standards of the Pennsylvania system. Mr. Cushing is well known as a painstaking recorder of engineering facts, and his detailed report on experiences with special steels in track work is one of the most exhaustive of the kind we have seen. It points out that the maximum engine axle load which now has to be considered, is one of 75,600 lb. (on the P.R.R.–N 1 s type of engine), and that to meet modern requirements special high-element steels have been tried, as well as alloy steels and steels produced by special processes. Dealing first with high-element steels of which manganese steel was the most prominent, such steels had been most successful for points and crossings. The characteristics were toughness and resistance to abrasion, and the economy in many locations had been definitely determined. For rails however, the advantages were not so clear. Such rails gave a low elastic limit, and the number of breakages was large, the standard section being difficult to roll in manganese steel without quenching with possibly the formation of minute cracks. The material was strong and tough, but not superior to the Bessemer product, and the present cost was prohibitive. The rails could not be drilled or cut on the work. High carbon rails had not been extensively employed. Nickel steel rails had been tried in a limited way, but up till the present had not proved entirely satisfactory. The proportions of nickel and chromium so far tried in nickel chromium steels gave quite unsatisfactory results, but it was recognised that other proportions might prove more successful. Titanium and vanadium were used as correctors and deoxidisers, but tended to much deeper piping which had to be guarded against. They certainly tended to improve the product if the necessary steps for this were taken. Aluminium served the same purpose, but its use was actually prohibited in some cases. Heat-treated rails were in the experimental stage only. The future for these systems seemed to be promising. Electric steels had only been tried on quite a small scale. Special processes of manufacture, such as the Hadfield sink-head ingot process, appeared to have given good results in trials on the Pennsylvania Railroad. The Sandberg sorbitic process in which the rail head was cooled by an air-blast, had been tried on the Pennsylvania Railroad, but its use had not been followed up.

Experience with special steels has been somewhat obstructed in France, as Mr. Mesnager pointed out, by the fact that in most cases the concessions granted to the railway companies are drawing to a close, and it is considered that ordinary materials will last on the whole, long enough. However, special steels are employed for crossings and places subjected to exceptional wear. The Eastern Railway laid a good many crossings of manganese steel, but has put down none since 1914. The Orléans Company, after various experiments, decided to adopt manganese steel crossings as a standard. The Eastern Algerian Railways had successfully used manganese steel for expansion rails on bridges, and rails laid in 1908 had shown no sign of crushing. The P.L.M. Company had laid Sandberg sorbitic rails, but the period in use had not been long enough for conclusive results to emerge. The Orléans Company tried titanium steel rails, but though they showed a longer life than ordinary steel, they had been abandoned in favour of manganese steel. Mr. Mesnager's report proceeds to discuss the question of examining the transverse surface cracks which appear in rails subjected to hard wear, and then gives the experience of tramways with special steels. From these it appears that manganese steel has proved satisfactory for rails, in spite of the high price. Sandberg high silicon rails did not present sufficient advantages. Nickel steel of certain proportions appeared to give promise of good results. In general, French railways did not favour the hardening of rails.

The report by Mr. Sand of the Swiss Federal Railways, mentions the use of manganese cast-steel crossings on several English Railways, and also on the Netherland State and other railways, but furnishes comparatively little information on the economic side of the question. He further discusses the use of the Sandberg high silicon rails on the Metropolitan Railway and Great Central Railway, both of this country, and presents a number of test results on such rails. The report states that the extra life obtained, up till the time of writing, by repeated weighings, promised to be an extension of life of the order of 32 per cent. on rails laid by the former railway.

The conclusions arrived at by the Section which discussed the use of special steels for trackwork were only definite on one point, namely, that cast manganese steel, containing 12 per cent. of manganese and 1·3 per cent. of carbon, gave excellent results and was economical to use for crossings, and especially for crossings cast in one piece. It was also advantageous for rails on small radius curves where the speeds were low and the service frequent. With regard to other special steels, opinion was not unanimous, and no general acknowledgment of the special advantages of any of them was obtainable. A few engineers thought that the tempering of rails improved their characteristics, but most were opposed to the practice except where it was desired to obtain a sorbitic structure. With regard to manganese steel, it was felt that further experiments were advisable in order to determine the best conditions for its use, and an enquiry into the actual value of other special steels for particular purposes was also suggested. Coupled with these recommendations was one advocating an enquiry into the whole question of the causes of rail fractures in service.

Net Cost Rates.

Three reports on the determination of the costs of transport (passenger and freight) including

capital charges, and the relationship of such costs to railway rates were considered by Section IV on April 20. These reports were prepared by M. Henry-Gréard for European and English-speaking countries excluding Germany and the United States, and by Messrs. Fairfax Harrison and Samuel O. Dunn for the United States.

M. Henry-Gréard reviewed the history of the question of separating out costs and apportioning the proper amount between passenger and freight services. The replies he had received to questionaires showed that few companies thought the matter capable of sufficiently definite solution for it to be of value to follow it up. However, M. Henry's report proceeded to point out how costs might be apportioned both as regards operating and capital costs, by a minute sub-division and proportioning according to some accepted basis representing traffic. His conclusions were that the splitting up of total working costs and capital charges between different classes of traffic was possible, if each item were analysed and concrete check cases were taken. The results obtained could not be absolutely correct, but furnished useful information. The net cost of service, however, could not form the basis for rate-making, but might be useful in connection with rate investigations.

Very similar conclusions were arrived at in the other reports. That by Mr. Harrison was very detailed, and traced the history of the question in the United States up till 1914, and the requirements in this connection of the Interstate Commerce Commission. This report gave in detail the methods adopted of splitting up the various factors in accounts, but as this has been superseded we need not further refer to it. Some very interesting later details of procedure were given in Mr. Dunn's report, from which we may abstract the following: As regards operating costs, the Inter-state Commerce Commission required all costs to be assigned on a definite plan. The direct-charge method applied to about 66 per cent. of the total working costs. Other expenses were apportioned on definite bases such as shunting-miles for yard maintenance, train despatching on transportation train-miles, track maintenance on locomotive fuel costs, and so on. These accounted for another 14·9 per cent. of the total. The remaining 18·5 per cent. of the costs were allotted in a combined proportion representing the two above. This was only approximate, but was a satisfactory working method. Mr. Dunn was of opinion that as regards capital charges no method had been, or ever could be, devised of apportioning these between freight and passenger services, but they might for an approximation be allotted in proportion to the operating expense proportions. The Inter-state Commission method made practicable the drawing of correct general conclusions as to the relative operating costs of freight and passenger service. From such an analysis enough information could be derived to throw light on the way rates might be adjusted, but no system ever would be devised of showing accurately the costs, including capital charges, of all the services performed by railways, nor if actual costs were ascertained could they be taken as more than one among many guides in the fixing of rates.

A summary of the three reports was presented by M. Henry-Gréard. After listening to the discussion one was left with the impression that no very satisfactory basis existed for determining costs, and that everything depends upon the simplifying assumptions which have to be made in order to render the problem manageable. Sig. Serani, of the Italian State Railways, considered that the axle-mile furnished a unit upon which a system of cost-keeping might be founded, the assumption being that a fast axle-mile cost as much as a slow one. Under criticism, the inventor of the system admitted that the figures would only have a comparative value. Mr. Cesar Mereutza, of the Roumanian State Railways, maintained, though for a not very obvious reason, that the study of net cost should not be conducted on State Railways in the same way as on lines belonging to private companies, and he considered that to use the net cost as a basis for fixing rates, particularly on State systems, was not justified. The final conclusions of the Section on the subject of determining costs are somewhat disappointing to those who hoped that a more or less scientific method of costing might have been recommended. The delegates found that the splitting up of total expenditure between different classes of traffic was possible, but only by analysing each head of expenditure, and if necessary examining concrete cases. The statistical method which the Inter-state Commerce Commission of the United States enforces on railways permits the allocation of operating cost to be made between various classes of traffic. The allocation of capital charges, however, presents such difficulties that it can only be carried out by making arbitrary estimates. Under such conditions the results obtained are necessarily very approximate, and are only of value in giving a rough indication of the relation between the net costs of each class of traffic. It is considered that the net cost neither is, nor can be, the determining factor in making rates on any railway, although it is held to be a useful element in the investigations connected therewith. Where such investigations are directed to the development of traffic by means of a modification of rates, the net cost of the existing traffic should not be alone considered, but rather the cost of carrying the additional traffic.

(To be continued.)

NEW SERVICE RESERVOIRS FOR LONDON.

Fig. 1.

Fig. 2. ELTHAM RESERVOIR

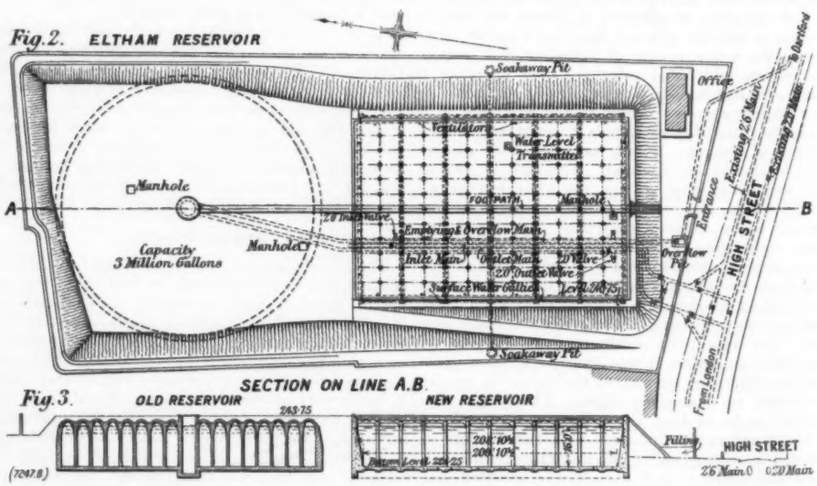


Fig. 3. SECTION ON LINE A.B.

NEW LONDON SERVICE RESERVOIRS.

WITHIN the past two years a number of service reservoirs have added to the Metropolitan Water Board's facilities in their Kent district, extending south-east of London. These reservoirs form a rather interesting chain of development to standards which we understand are to be adopted for future work, and through the courtesy of Mr. H. E. Stilgoe, M.Inst.C.E., chief engineer to the Board we are enabled to give particulars of some of the features of their construction.

The map given in Fig. 1 shows the position of the various reservoirs we now refer to, and the pumping stations with which they are linked up. It is hardly necessary to point out that in this map the lines joining pumping stations and reservoirs do not represent the alignment of the pipe lines, but are merely

NEW SERVICE RESERVOIRS FOR LONDON.

ELTHAM RESERVOIR

Fig. 4. SECTION A.B. (Fig. 7.)

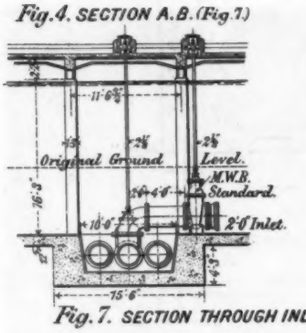


Fig. 5. SECTION C.D. (Fig. 6.)

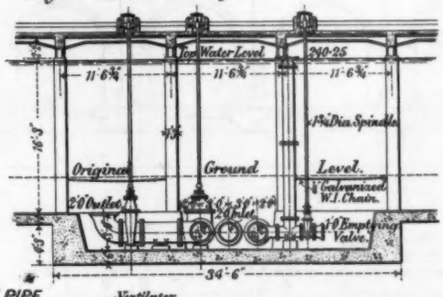


Fig. 6.

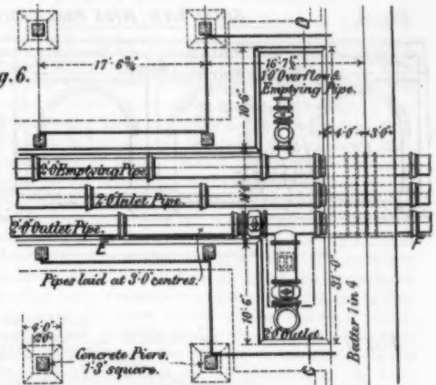


Fig. 7. SECTION THROUGH INLET PIPE.

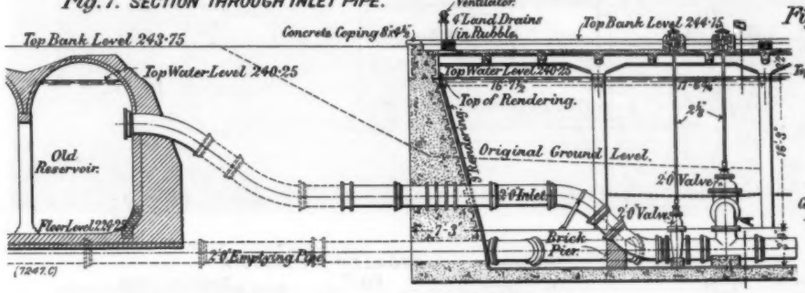


Fig. 8. SECTION AT MANHOLE.

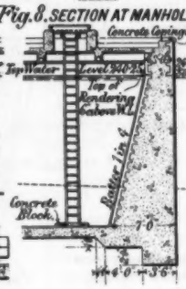


Fig. 9. SECTION E.F. (Fig. 6.)

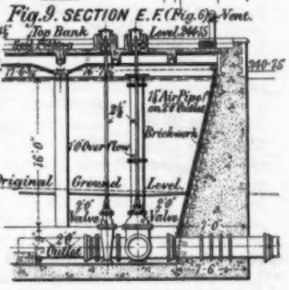


Fig. 10. LONGITUDINAL SECTION OF SECONDARY BEAMS.

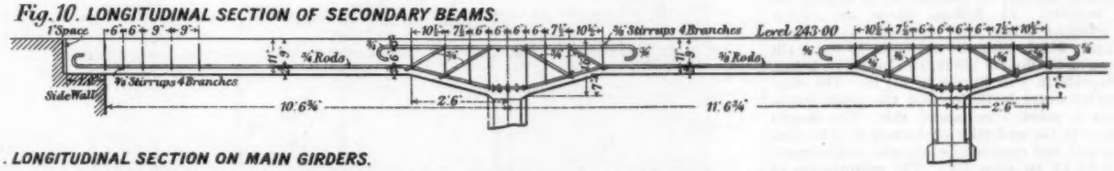


Fig. 11. LONGITUDINAL SECTION ON MAIN GIRDERS.

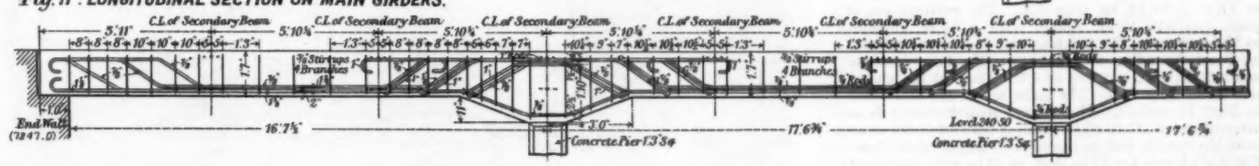


Fig. 12. MAIN GIRDER.

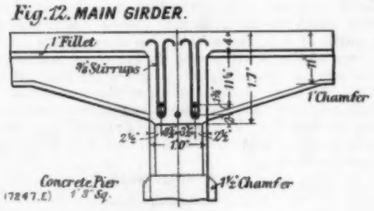
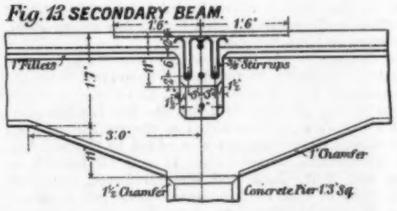


Fig. 13 SECTION BEAM.



inserted to assist reference to the map. The new reservoirs are at Shooters Hill, Eltham, Bromley, Bickley and Farnborough, with Betsom's Hill and Westerham Hill reservoirs towards the southern extremity of the area. The Shooters Hill reservoir supersedes an older one not far from the present site, and is supplied by three pumping stations, namely Deptford, Orpington and Crayford. The Eltham reservoir is in connection with the pumping stations at Shortlands, Wansunt, Dartford, Wilmington and Darenth, the four latter being coupled to one main to Eltham. The Bromley reservoir is normally supplied from Shortlands, but a line connects with the Eltham main just referred to, and so this reservoir can be supplied if necessary from any of the four stations on it. The Bickley reservoir is in connection with Shortlands pumping station only. Farnborough reservoir receives its supplies from either West Wickham or Orpington; while Betsom's Hill and Westerham Hill reservoirs both derive their supplies from the Westerham Hill pumping station.

The Eltham reservoir is built to the Board's latest designs, and the contrast with the older reservoir alongside it is interesting. The two are illustrated in plan in Fig. 2, while a small scale section is given in Fig. 3. Further details of Eltham are given in Figs. 4 to 13, annexed, to be referred to later. The old reservoir as will be seen is circular in plan and is provided in the interior with a series of circular walls, communication being provided between the several rings so that the water, admitted at the outer circumference flows in a steady stream in a decreasing circular path towards the centre whence it is drawn off through the outlet main. The object of this construction was to keep the water in constant circulation, but in view of the amount drawn off these reservoirs daily it is now thought there is very much less in this idea than was formerly supposed, and the later reservoirs have been greatly modified with a view to eliminating costly features of interior construction. The gradual departure from this idea of requiring circulation of the water, is well illustrated by later reservoirs such as those at Shooters Hill, Westerham and Betsom's Hill and Farnborough and Eltham. A view is given of the Shooters Hill reservoir during construction in Fig. 18, page 615, and two sections in Figs. 14 and 15, page 614. The circular construction of the old Eltham reservoir had been abandoned, and in the Shooters Hill reservoir a rectangular lay-out was adopted. The reservoir was divided by a number of parallel cross walls of brick centred 13 ft. 10½ in. apart, each wall being pierced by a single arched opening 4 ft. wide and rising to 6 ft. above the floor level. These openings are placed at alternate ends of the cross walls so that in passing from end to end of the reservoir the water flows in a zigzag course, first across the reservoir and then back again and so on. In the old Eltham pattern of reservoir the roofing was of brick arching. In the Shooters Hill and later reservoirs roofing is of reinforced concrete. This we shall revert to later.

The abandonment of the circulation principle is illustrated in the design of the Westerham reservoir. In this instance the partition walls are eliminated, and the interior brickwork confined to the provision of the pier and arches necessary for the support of the roof. A view of the interior of Westerham reservoir is shown in Fig. 19, page 615, the water having freedom to flow between the piers from the inlet to the outlet end. The development to this stage naturally suggested the abolition of expensive brickwork arching in favour of construction still further simplified, and the new Eltham reservoir is built on such lines, with reinforced concrete roofing supported on plain concrete pillars. Farnborough reservoir which is similarly constructed is illustrated in the two Figs. 21 and 22, page 622, while a view of Eltham during construction is given in Fig. 20 on the same page. Of these illustrations the last gives a good idea of the supporting columns, while Fig. 21 illustrates work on the roofing slabs and the reinforcement employed. Fig. 22 shows the general appearance of the completed interior.

The new type of reservoir of which Eltham, Farnborough, Bromley and Bickley are representative, is intended to be built to standard, as far as possible, making any small modifications as the site may require. The standard unit is a rectangle 11 ft. 6¾ in. by 17 ft. 6¾ in., and throughout the interior this is the

NEW SERVICE RESERVOIRS FOR LONDON.

Fig. 14.

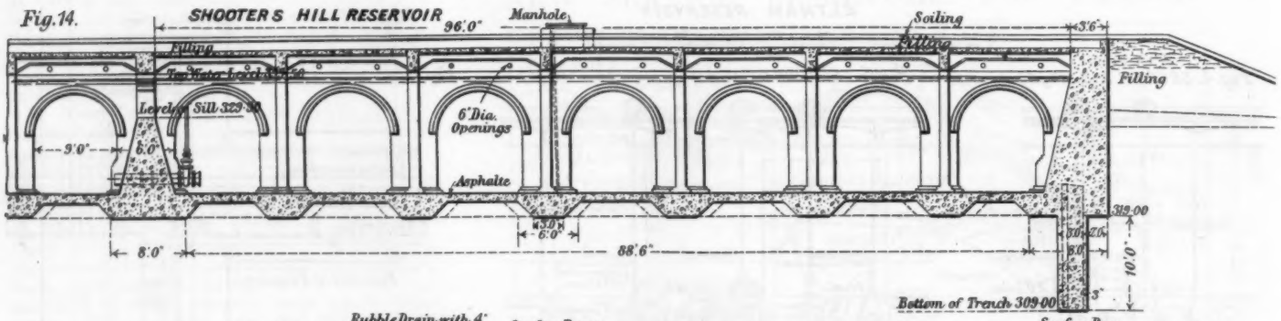
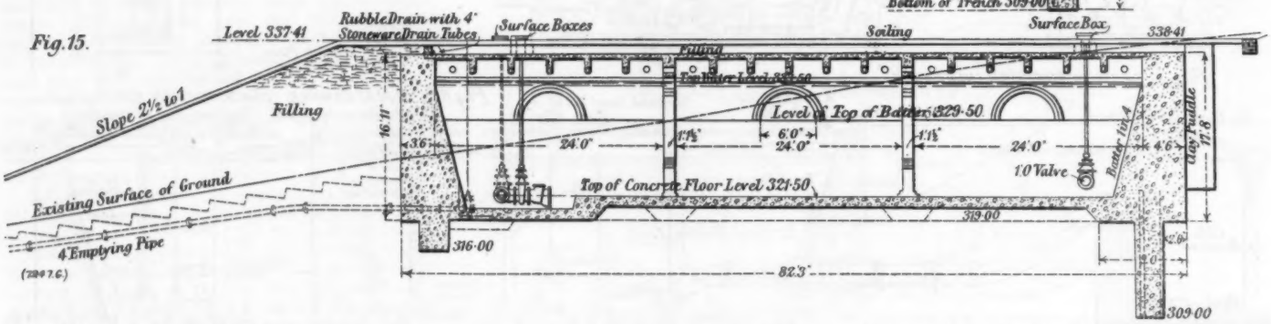


Fig. 15.

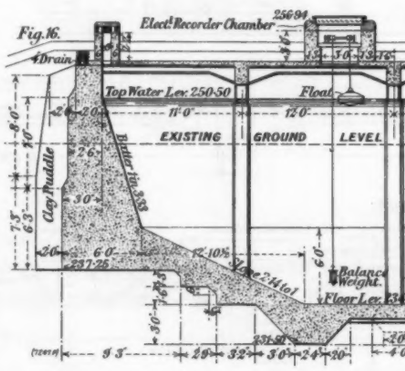


spacing of the columns. Normally future reservoirs will be constructed as rectangles of suitable multiples of this unit, or as near as possible to it, to give the capacity required. At Eltham there are eleven rows of columns across the reservoir, and eleven to the length, which with the surround to the walls gives an area on the floor of 128 ft. 9 in. by 200 ft. 10½ in., or at the top 136 ft. 9 in. by 208 ft. 10½ in. The standard depth of water is 16 ft., and the main beams spring from a point 3 in. above this. The height from the floor to the underside of the roof is 18 ft. 5 in.

The standard roof construction adopted is illustrated in Figs. 10 to 13, on page 613. The columns are of plain concrete 15 in. square with a 1½ in. chamfer to the corners. The columns rest in normal ground, on bases extending to 1 ft. below the floor concrete and 2 ft. square, tapering to 4 ft. square at the underside of the floor slab. The main beams are illustrated in Figs. 11 and 12. The normal span for these is as already stated, 17 ft. 6¾ in.; this is reduced in the span from the outside wall to nearest column, to 16 ft. 7½ in. The main beams are 19 in. deep by 12 in. wide, deepened at the columns to 30 in. The standard reinforcement is shown in the illustrations, the bars being of ⅞-in. diameter. In two outside beams additional reinforcement is provided in the end length and between the wall and first column, at either end of the reservoir. This is not shown in our figures. At the ends the beams rest on the side walls for a distance of 1 ft. The secondary beams, Figs. 10 and 13, are 11 in. deep by 9 in. wide. The depth is increased to 19 in. where these beams run into the main beams either at the piers, or at the intermediate points, the secondary beams being spaced 5 ft. 10½ in. apart. The roof slab is 4 in. thick with mesh reinforcement placed 1 in. away from the upper and lower surfaces. Fig. 21, page 622, gives a good idea of the work on the roofing. In this case which, as already stated, illustrates Farnborough, and at Eltham, twisted reinforcing bars were used, as none others were available at the time, but plain round bars bars are standard practice, and these are used in the case of reservoirs at Bromley and Bickley.

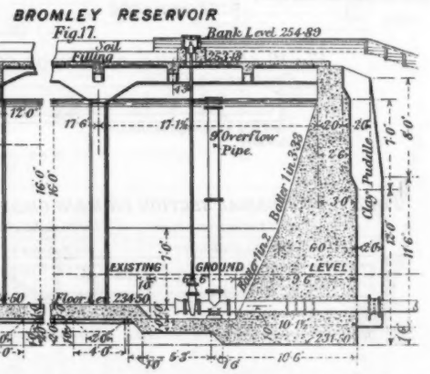
The illustrations, Figs 4 to 9, page 613, which show details of special features of Eltham, also illustrate in Fig. 8 the standard wall and floor sections. The floor is of 12-in. plain concrete, while, for the standard depth of 16 ft. of water, the outside wall has at Eltham a section of 3 ft. at the top, increasing to 7 ft. width at the base, this reservoir being constructed in a sand formation. The base width is varied according to the class of backing to the wall. The footing of the wall is carried down as a rule to a depth of 4 ft. below floor level, being rather lower at the pipe channels and sump in which the outlet valves are situated, as shown in Figs. 4, 5 and 9, &c. At Eltham the pipe and valve arrangements were complicated by the fact of the old reservoir being situated beyond the new, and the pipe connections to the old, hence had to be carried through the new. This, however, allowed three mains only to be

Fig. 16.



BROMLEY RESERVOIR

Fig. 17.



used for the two reservoirs, for inlet, for outlet, and for overflow and emptying, either for the one or the other, according to the setting of valves.

In the case of the Shooters Hill reservoir which was situated on sloping ground as will be evident from the illustrations, Figs. 14 and 15, and also the view reproduced in Fig. 18, page 615, the site was London clay, and a deep tongue was added to the wall to prevent any sliding before support was added to the walls by the floor. This tongue (Figs. 14 and 15) was 10 ft. deep and 3 ft. thick and was reinforced by rolled steel joists of 6 in. by 5 in. section arranged vertically at 6 ft. centres, and ⅝-in. rods 2 ft. long arranged horizontally at these joists and 9 in. apart, 3 in. from the inner surface of the tongue. Three inches from the outer surface vertical ⅝-in. rods were spaced 5 ft. apart, and horizontal continuous ⅝-in. rods 9 in. apart. We may mention that in the Shooter's Hill reservoir a partition wall or sill divides the storage area into two so that either part can be emptied for repairs. This reservoir stores water to a depth of 12 ft., and the sill partition level is 4 ft. below normal water level so that about 8 ft. of water can be stored with one half empty.

At Farnborough the site is partly on clay, and where this occurred a similar tongue wall to that at Shooters Hill was adopted. At Bromley conditions were rather different, the site being on London yellow clay, which is particularly treacherous. The ground level also sloped considerably in one direction and it was decided to keep the excavation for the side walls as shallow as possible until sufficient support was secured by the floor. The contract required that the base of the wall should be supported by a width of at least 50 ft. of floor before the filling behind the wall was brought to a height of 4½ ft. In order to lessen the deep excavation at the walls the construction illustrated in Fig. 16 was adopted, a slope of about 2 : 1 rising from the floor to a height of 6 ft., from which the wall section proper commences with a width of 6 ft. and a batter on the inside of 1 : 3·33. A view of the Bromley wall during construction where this section was adopted is given in Fig. 23, page 622. At parts of the site where the excavation and back fill were not excessive the more normal wall section shown in Fig. 17 was adopted, the interior being built to batters of 1 in 2, and 1 in 3·33 for the upper portion.

(To be continued.)

WATER POWER IN INDIA.—In a recent report compiled by the Hydroelectric Survey of India, the water resources of that peninsula are estimated at a maximum of 21½ million h.p., of which but 1½ per cent. is either developed or in course of development. The North West Frontier Provinces and the Punjab are the best provided, with developable water power, whilst in Central India little or none will be available.

SMOKELESS FUEL FOR DOMESTIC FIRES.—An investigation made by the American Bureau of Mines has shown that about 27 per cent. of the smoke from which Salt Lake City suffers comes from domestic fires. This proportion seems very small, but nevertheless it has led to an inquiry into the feasibility of establishing a local supply of coke to take care of domestic heating requirements. The Bureau found that the installation of a by-product plant of sufficient size to supply the entire domestic demand of Salt Lake City for coke fuel is not economically feasible unless municipal legislation prohibiting the production of smoke is obtained. By education and legislation consumers must be induced to pay 3 dols. more per ton for smokeless fuel than for the ordinary bituminous coal in order to make the carbonisation plant a success. While the coke and by-products of a low temperature carbonisation plant would probably find a readier market than those of a standard high temperature plant, neither plant would be a commercial success without such protective legislation.

NEW SERVICE RESERVOIRS FOR LONDON.

(*For Description See Page* 612.)

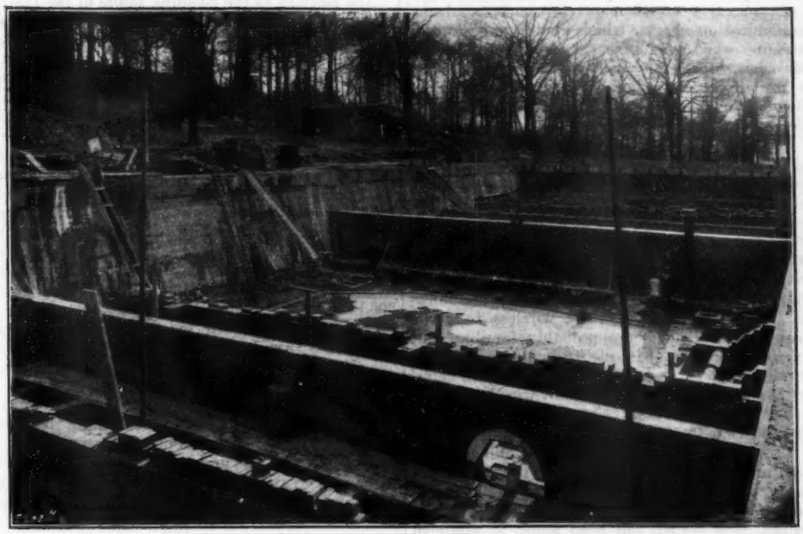


FIG. 18. CONSTRUCTION OF SHOOTER'S HILL RESERVOIR.

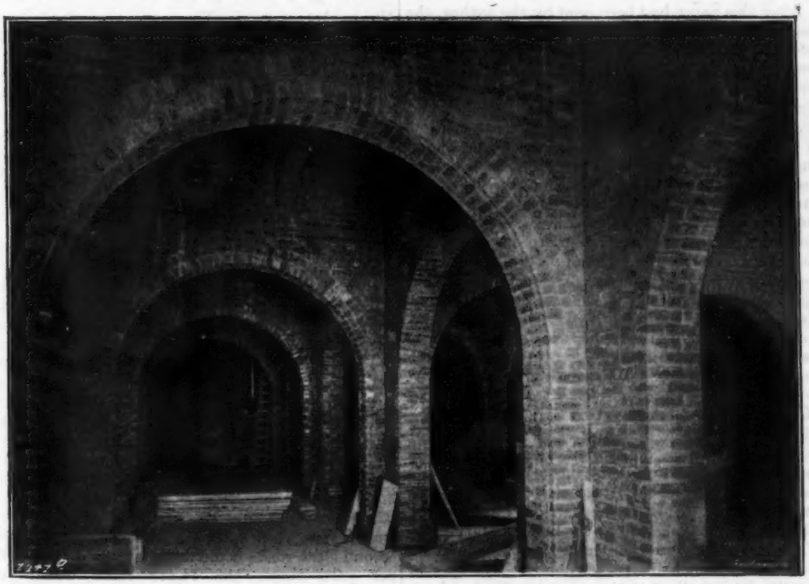


FIG. 19. INTERIOR OF WESTERHAM RESERVOIR.

THE INSTITUTE OF TRANSPORT CONGRESS.

THE second annual congress of the Institute of Transport, which commenced in London on Wednesday last and terminates to-morrow, was preceded on Tuesday evening by a reception at the Hotel Metropole, where the members and delegates were welcomed by the president, Sir Henry P. Maybury, K.C.M.G., C.B. The general programme includes the reading and discussion of a number of papers in the morning, visits to works and other places of technical interest in the neighbourhood of London in the afternoon, with social functions in the evening. Most of the papers were read in the Hall of the Institution of Civil Engineers, meetings being held simultaneously in the lecture theatre and reading room.

The President, who took the chair at the meeting in the lecture theatre on Wednesday morning, first remarked that the conference would be opened by the Right Hon. Stanley Baldwin, M.P., the President of the Board of Trade. Mr. Baldwin, in the course of a short address, pointed out that cheap transport was a vital necessity for this country, and that our industrial and social prosperity were deeply dependent on the solution of the problems before the congress, which he then declared open. After a vote of thanks to Mr. Baldwin, proposed by the chairman and seconded by Sir Sam Fay, had been carried, the chairman welcomed the foreign delegates on behalf of the Institute, and also said he wished to express the thanks of the Institute to the President and Council of the Institution of Civil Engineers for having allowed their hall to be used for the congress. To this Mr. W. B. Worthington, President of the Institution of Civil Engineers, briefly responded. The Chairman then called on Sir C. R. S. Kirkpatrick to read the first paper on the programme, bearing the following title:—

TRANSPORT FACILITIES IN THE PORT OF LONDON.

In this paper, the author dealt with recent improvements in the transport facilities in the Port of London, and mentioned that goods to the value of about 1,800,000*l.* arrive each day in the Thames and have to be discharged and stored, and afterwards transported to their destination by rail, road, river or canal. Rapid means of communication, he remarked, were therefore essential for all concerned, and the problem presented was of no small dimensions. After giving some interesting statistics as to the activities of the Port of London Authority, the author described the improvements recently made and indicated where he considered further improvements were necessary, dealing in this way with the river, docks, jetties, railways, roads, mechanical equipment, the discharge and storage of meat and grain, the storage of tobacco, and the landing and embarking of passengers. A brief description of the new King George V Dock was given in the paper, but as we have already illustrated and described this dock fully on pages 2 and 109 of our 112th volume, we need not deal further with it here. Another recent improvement mentioned was the construction at Tilbury of a reinforced concrete cargo jetty, 1,000 ft. in length and 50 ft. wide, with two decks. On the subject of roads, the author remarked that the port was badly equipped with road access outside the docks. The main approach to the King George V Dock, he pointed out, was by a roadway only 21 ft. wide, passing over two level crossings and a swing bridge, the latter only 11 ft. wide; the alternative route, he added, necessitated passing over three level crossings and a swing bridge. The trouble was that so many municipalities and other bodies were interested that it had not been possible to bring sufficient pressure to move them to action, but the matter was now being considered by the Ministry of Transport. In giving particulars of the crane equipment of the docks and sheds, the author mentioned that to provide increased outreach without having to travel the load through a longer radius, two new T-headed cranes had been constructed and installed experimentally on the south side of the King George V Dock. The cranes, he added, travelled in the ordinary way, but the T-head revolved in a complete circle and had on top a 3-ton travelling crane of small radius. These cranes, however, had only just been completed, so that the results obtained could not be given, although it was anticipated that a considerable saving in the time of working would be effected by their use. Additional facilities, the author continued, had recently been provided at the Royal Albert Docks for the discharge, sorting and storage of 646,000 carcases of mutton. The whole of the operations involved in handling these, he said, were conducted mechanically in a temperature of 17 deg. F. The methods of dealing with cargoes of chilled beef were also briefly referred to. With reference to grain, the paper stated that 1,000,000 tons were discharged annually, a fleet of 16 bucket and 8 pneumatic floating elevators being used for the purpose; the warehouses, he added, were capable of storing 128,600 tons of wheat at one time. It was now proposed to construct four more floating elevators and to equip 2,100 ft. of quay at West India Dock with travelling pneumatic appliances. Developments in the method of storing hogsheads of tobacco were referred to, and finally reference was made to the floating landing stage which it had been decided to construct at Tilbury for landing and embarking passengers of ocean liners. The floating stage would have a length of 1,700 ft. and a width of 80 ft., and would adjoin Tilbury Station of the Midland Railway. It was anticipated that the work would be commenced early next year.

After this paper had been read in full by the author, the discussion was opened by Mr. D. Ross Johnson, who, after a few remarks relative to the effect of vested interests on dock management, pointed out that the width of the King George V Dock would not apparently permit a vessel to be turned in it, and asked how this was done. He also inquired how the coaling operations were carried out at the barge jetties on the south side of the

dock. Another question raised by the speaker was whether cranes would not eventually be replaced by elevators of various kinds for handling goods. Mr. Marshall Stevens, who followed, said the paper was interesting in that it showed the degree of co-operation reached between engineers and dock managers. He thought the time was coming when the whole question of cranes would have to be reconsidered. At Manchester it was found essential to take a great deal of the traffic directly by rail from the side of the ship to sheds some distance away. He was particularly interested in the T-headed cranes referred to, and remarked that the radius of a crane was now a matter of great importance, although formerly it had hardly to be considered at all.

The next speaker, Mr. W. H. Gaunt, remarked that he had found occasion previously to criticise the Port of London Authority, but had noticed a great improvement during the last two years. He pointed out that the greater part of the traffic from the London docks was dealt with by barges, although only a brief reference to barge traffic was made in the paper. He suggested that floating cranes would be advantageous to assist in loading barges from ships and said he would be interested to hear more fully how miscellaneous cargoes, as distinguished from bulk cargoes, were handled.

Sir Joseph G. Broodbank, the only other speaker on this paper, considered the author had rather understated the case, since he had omitted to mention that a considerable export trade was dealt with at the London Docks. The speaker also thought it should be explained that an enormous amount of accommodation at the docks had been provided by private enterprise. With reference to Mr. Ross Johnson's query as to the coaling of ships, the speaker pointed out that the jetties referred to were used for discharging ships, whereas bunkering was usually carried on while a ship was loading. It was a fact that about 90 per cent. of the traffic in the London Docks was distributed by barges, and that had to be considered in the mechanical handling of goods. The creeper, or elevator, system had been used for a considerable time for handling case goods, but he thought the real solution to the whole problem was the proper stowing of goods on the ship at the distant port. Much time and money would be saved if shipowners would attend to the matter of loading ships.

The chairman, who then proposed a vote of thanks to the author, also remarked that the roads communicating with the docks were very bad, and improvement was overdue. The work, however, would be very costly, but it ought to be faced, and he would do his best to get it carried out. Sir C. R. S. Kirkpatrick, who then replied to the discussion, said in answer to Mr. Ross Johnson's question as to the turning of ships in the King George V Dock, that the ships were always turned in the river. The question as to barges and bunkering, the speaker thought, had been answered by Sir Joseph Broodbank. With regard to the question of elevators *versus* cranes, the speaker thought the former had many advantages, but pointed out that there was a difficulty with mixed cargoes. The point raised by Mr. Marshall Stevens, with reference to railway lines, the speaker remarked required considerable thought, and the question was too large to go into at that time. In connection with Mr. Gaunt's remarks as to handling goods by barges, the speaker pointed out that the reason that such a large proportion of goods were dealt with in that way in London was that barges were exempted by an old Act of Parliament from the payment of dues. He did not think it would be any advantage to provide more floating cranes, although such cranes had proved useful in Continental ports. In the London Docks it was found preferable to bring the ship to the crane instead of moving the crane to the ship. In conclusion, the speaker remarked that he was glad to have been able to draw Sir Henry Maybury on the question of road improvements.

WIRELESS COMMUNICATION IN TRANSPORT.

The second paper taken was entitled "Wireless as an Aid to Transport," its author being Captain H. Riall Sankey, C.B., and its subject matter relating to the use of wireless communication in connection with travel by sea, air and land, both as regards past achievements and future possibilities. Dealing first with marine applications, the author referred to the assistance to navigation derived from the transmission by wireless of time signals, meteorological information, and navigation warnings, and also mentioned its importance in enabling passengers at sea to carry on their private correspondence. Communication charts, which enable operators to determine when communication can be established with other ships, were briefly explained, as also was the use of direction-finding apparatus. The so-called "four-second alarm" device, by which the necessity for keeping a wireless operator constantly on watch at sea, is avoided, was also mentioned, and reference was made to the recently invented wireless beam in which very short waves are concentrated by means of a reflector into a more or less parallel beam. Predetermined signals can be sent out in this way and a ship passing through the beam can readily obtain a bearing on to the source, the position of which would be known; the beam system can also be used for telephonic communication. With the application of wireless to aerial transport, our readers are probably familiar, but numerous instances of its utility in this connection are referred to in the paper. In conclusion, reference is made to the possibilities of wireless in connection with road and railway transport. It is suggested that it may be used to transmit instructions from headquarters to lorries travelling on the roads, and the fact that wireless telephony has already been used experimentally on certain railroads in the United States is mentioned. Signal strength, it is stated, had been found to diminish considerably when a train was travelling through cuttings or over bridges, although the apparatus functioned quite well in tunnels.

After this paper had been read by the author, the discussion was opened by Mr. Roger Smith, who referred to some experiments carried out on the Great Western Railway in October, 1919, on the reception of wireless signals on a moving train. Signals transmitted from Woolwich, he said, had been successfully received throughout the whole of the journey on a train travelling between London and Bristol. A subsequent attempt to transmit from the train to Woolwich had, however, been only partially successful, the signals having failed from jamming after about 70 miles from London had been covered. He particularly wished to emphasise the fact that these experiments had no connection with the substitution of wireless apparatus for fixed signals for controlling the movements of trains. Mr. G. N. Nash, the next speaker, said that transport engineers should take steps to secure a definite wave length for their work, as otherwise all wave lengths suitable for telephony would be allotted to other users. He also referred to the utility of the system of communication known as "wired wireless," in which by using currents of different frequencies a large number of separate messages could be transmitted simultaneously on a single pair of wires. Colonel Cortez Leigh then gave some particulars of experiments carried out by the Marconi Company in 1920 on the London and North-Western Railway in communicating with moving trains by means of wireless telephony. The speech, he said, was excellent at times but trouble had been experienced by jamming.

The chairman, after proposing a vote of thanks to the author, called upon him to reply to the discussion. Captain Sankey then replied, saying that he had been very interested in the contributions of Mr. Roger Smith and Colonel Leigh. He remarked, however, that the failures recorded at critical moments would prevent wireless communication from being used in connection with train movements. It would, however, be of considerable utility for less responsible work. He had not mentioned "wired wireless," as he regarded it as distinct from what was generally meant by wireless telegraphy or telephony. The speaker did not himself possess expert knowledge of the system, but he understood that it was not possible to carry on more than six duplex conversations simultaneously by wired wireless. With regard to wireless generally, the little adjustments necessary were difficult, and it was not always easy to distinguish between wireless sounds and other sounds. Good results, however, were usually obtained, although failures sometimes occurred.

On the conclusion of Captain Sankey's remarks, the meeting adjourned.

HIGHWAY CONSTRUCTION AND MAINTENANCE.

The meeting in the Reading Room of the Institution under the chairmanship of Mr. A. Dryland was concerned with a paper by Col. C. H. Bressey, entitled "The Design, Construction and Maintenance of Highways, in relation to the development of mechanically-propelled vehicular traffic." The paper referred to the "unexampled change" which had taken place in road traffic in the last 30 years, and quoted 6,000,000 tons per annum of road traffic passing in and out over the Liverpool city boundary. Of 3,000,000 tons using the Prescot Road route, 95·3 per cent. was motor tonnage. In the Upper District of Renfrewshire mechanically-propelled vehicles represent 90 per cent. of the total volume of traffic, while on portions of the Great North Road in Durham the total traffic increased in weight 290 per cent. between 1912 and 1920.

Col. Bressey then referred to road widening, and pointed out the advantages in many cases of striking out along an entirely new line instead of attempting to widen, improve and straighten existing roads. If a by-pass was constructed instead of attempting to deal with an old, narrow crowded main thoroughfare, a useful alternative route was provided when the original road was under repair and fresh rateable value was created, whereas it was not infrequently destroyed in the widening of an old high street. Ideas of this kind could, of course, best be carried out when the by-pass could be made in comparatively open country, and many desirable schemes had been put in hand during the past eighteen months as a result of the Unemployment Relief Works Act of 1920. The paper then dealt briefly with the various projects being carried out in the neighbourhood of London, and gave a sketch of existing legislation affecting the question of the building line. In many cases when a by-pass is constructed there is nothing to prevent the old main road beyond the junction of the by-pass being built up and in time forming a congested point, and legislation was desirable to secure control over the building line of arterial roads, so that in future widening when necessary could be carried out without the present heavy expense.

Turning to questions of cost, Col. Bressey stated that "no one questions that the roads of the United Kingdom need reconstructing." Considering resurfacing only, however, and assuming that the existing foundations can be relied on, he suggested 10*s.* a yard super. as a possible average cost in the future. This figure was based to some extent on successful work at Hornsey, Sheffield, &c., with a clinker asphalte which, laid 2 in. thick, cost from 9*s.* to 12*s.* per yard super. Taking the 10*s.* figure and assuming a carriageway 20 ft. wide, it worked out at some 6,000*l.* per mile run. The total length of first-class roads in the country, according to the Ministry of Transport's list, is 22,160 miles, so that the total cost of re-surfacing would be about 133,000,000*l.* Assuming that second-class roads could be re-surfaced for 7*s.* 6*d.* per yard super. the 14,419 miles would cost 65,000,000*l.*, so that the total for the two classes would amount to 198,000,000*l.* If this sum were borrowed at 5 per cent. and made repayable in seven years, it would represent an annual charge of 34,000,000*l.*, which might be compared with the total yield of 10,000,000*l.* last year from the tax on mechanically-propelled vehicles. The purpose of these figures was mainly to illustrate the magnitude of the problem which the roads presented. The matter was accentuated by the fact that these calculations allowed nothing for the 140,727 miles of third-class road which represented by far the greatest proportion of the total length.

The road question was a very difficult one to many small rural areas. There were highway authorities within 10 miles of St. George-street which administered for a population of less than 2,000. It was unreasonable to expect due provision to be made in such areas for the periodic migration of London's millions. Various aspects of this matter were referred to in the discussion which followed the paper, and the powers which have been

obtained by the Middlesex County Council in their General Powers Act of 1921 would appear of great importance. Mr. Dryland, the Chairman, and others were of opinion that the Ministry of Transport should bring forward a Bill to make these powers general. The Bill gives the Middlesex County Council powers to prescribe a building line for any road which is certified by the Ministry of Transport to be an arterial road or a road for the future widening of which provision should be made. It is clear that a general provision of this kind would do much to prevent the development of outer townships in such a way that they ultimately become traffic blocks, and necessitate expensive widenings. As bearing on this point, Mr. Dryland pointed out that up to the year 1909 no authority in this country had any power to make a new road. Under such conditions it is not matter for surprise that our road traffic should to some extent have outgrown the roads which are required to accommodate it.

The question of the third-class road was touched on by several speakers. Lord Montagu of Beaulieu, for instance, pointed out that while the Ministry of Transport contributes 50 per cent. of the cost of first-class roads and 25 per cent. of the cost of second-class roads, it did not contribute to the maintenance of third-class roads, which represented by far the greater proportion of the total roads of the country. The result was that there were hundreds of District Councils which had to face the modern traffic problem and obtained absolutely no financial assistance whatever. The third-class road presented in some ways the most difficult problem of all, and the best hope seemed to be in the direction of developing methods by which local material could be used for construction. On this question of third-class roads Col. Bressey, in his reply, pointed out that they were not entirely ignored by the Ministry of Transport. Where such roads were likely to be destroyed by the development of heavy traffic for which they were not constructed, the Ministry had power on application from the district authority to close the road to certain classes of vehicle. It should also be remembered that the road classification was not fixed for all eternity, and with the development of traffic third-class roads might be put up into a higher grade. Applications for financial assistance in connection with third-class roads were frequently made to the Ministry, and in many cases such assistance had been granted.

On the afternoon of Wednesday following these meetings a series of visits was arranged to various railway goods yards, power stations and other places likely to be of interest to those interested in transport matters. The visits included the Neasden power station, King George V Dock, Marconi House, the Great West Arterial Road and the Somers Town Goods Station of the Midland Railway.

In the evening the members of the Congress attended a Conversazione held at the Mansion House, the guests being received by the Lord Mayor of London and the Lady Mayoress.

(To be continued.)

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY.—The delegacy of the City and Guilds (Engineering) College, which forms the engineering section of the Imperial College of Science and Technology, have appointed Professor C. L. Fortescue, O.B.E., M.A. (Cantab.), M.I.E.E., of the Royal Naval College, Greenwich, to succeed Professor T. Mather, F.R.S., who is resigning the chair of electrical engineering in the college at the close of the present session.

NEW B.S.A. SHOW ROOMS.—The Birmingham Small Arms Company, Limited, which recently absorbed Messrs. Burton, Griffiths and Co., have opened new premises and wholesale show rooms at Chapter-street House, Chapter-street, Vauxhall Bridge-road, S.W. 1. They occupy the whole of a new building close to the well-known Burton-Griffiths building and but a short distance from Victoria Station. The basement of the new premises is occupied with machine tools, the ground floor with cars, the first floor with motor and pedal bicycles, and the second floor with small tools. The building is not a warehouse, and stock for sale is not carried in it. Only one example of each type of product is carried, and the exhibits are attractively arranged, with plenty of room around them so that they can be properly inspected. The display, particularly of small tools, is very extensive, and the showrooms should be a great convenience to the agents and wholesale buyers for whom they are intended. Some 30,000 sq. ft. are available for exhibits.

INDUSTRIAL NOTES.

THE Right Hon. W. C. Bridgeman, M.P., Secretary for Mines, announces that he has appointed Mr. Ben Turner, J.P., to be a member of the Coal Advisory Committee as one of the representatives of workers in other industries, in place of Mr. J. W. Ogden, J.P., who has resigned, and Mr. D. F. Gill to succeed Mr. Myles Kennedy, who has resigned his appointment as one of the representatives of owners of iron ore mines and quarries on the Advisory Committee for the Metalliferous Mining Industry.

No proposition of the older school of political economists was more vehemently denounced by workmen than the doctrine that wages were paid out of a wages fund. Of late years, however, the men have often acted as if they now accepted this view, but with the important amendment that the fund is unlimited in amount and can be drawn on to any extent. On any other hypothesis it is difficult to account for the steadily increasing tendency to strike. The older trade unionists recognised that a strike on a falling market was invariably futile, but to-day we meet with the claim that the workman is entitled to a certain standard of living irrespective of prevailing conditions. Indeed, at times the demand appears to be that though the community has been greatly impoverished by the war, organised labour, which took less than its share of the actual war risks (owing to the necessity of maintaining supplies) is entitled to get off scot free, and to transfer the whole of the burden to those whose sacrifices during the war were materially greater. It is most disappointing that absolutely unavoidable wage adjustments seem never to be effected without a futile strike, at the end of which the men accept the conditions which are essential to the carrying on of the industry. Unfortunately the workmen seem nowadays to act on the advice of Mr. Foxey Brass to his amiable children, as related in the "Old Curiosity Shop," and "always suspect everybody" whether it be their employers or their principal representatives. Many of the latter gradually acquire some knowledge of economic conditions, but over and over again their advice based on this knowledge is at first rejected, and finally followed only after great losses have been incurred by a useless strike. The essential point in the deadlock in the engineering trades has been the refusal of the men to accept the condition agreed to by their executive in 1921, that pending a settlement of disputed points the instructions of the management should be observed. This rejection seems wholly unreasonable, as the position of the men could not be seriously prejudiced by carrying on for a few weeks under protest, pending the permanent settlement. On this point Sir William Mackenzie reported: "On general grounds it may be concluded that the cases in which objection is raised to a direction by the management vary considerably in the matter of urgency. In some cases, any protracted discussion before the direction became operative, would be unreasonable; in other cases, the delay would be of slight importance. The person most competent to decide this question of urgency in any particular case is, in my view, the employer. The question of obtaining the prior consent of the workpeople before a direction becomes operative must not be confused with the question of prior consultation. To what extent consultation is possible again depends on the urgency of the proposed change. In some cases the period available might be very brief; in others it might admit of full discussion . . . but whatever the opportunities for prior consultation may be, it is reasonable and right that they should be fully utilised."

The conference between the unions and the Engineering Employers' Federation which was held during the week has resulted in new proposals based on Sir William Mackenzie's report being placed before the men's representatives. These are embodied in four clauses and provide for the application of the provisions for avoiding disputes to all sections and unions without distinction, and also suggested arrangements by which there would be reasonable notice given and prior consultation made possible in respect of contemplated changes in workshop management. These proposals were discussed at a meeting on Wednesday, at the conclusion of which the following official statement was issued: "The union representatives have been in negotiation with the employers, and have considered the proposals submitted for their consideration by the employers. Further questions were addressed to the employers and answers received, and the conference stood adjourned until Thursday morning. The union representatives will meet separately at 10 o'clock and will meet the employers in joint conference later."

It is stated that the shipyard trade unions, whose members are still remaining on strike in the non-federated ship-repairing centres in London and Liverpool, have decided to stop strike pay. The men are remaining out in an attempt to secure more favourable terms from the non-federated employers than the executives of the trade unions have accepted nationally from the federated employers. The London and Liverpool men took part in the national vote.

Mr. John Hill, the general secretary to the Boilermakers' Society, makes some characteristic comments on the engineering dispute. He refuses to admit that a lowering of costs was essential to the keeping in operation of our shipyards and engineering works, and appears to think that the whole trouble was engineered by the employers simply out of spite and a desire to degrade and debase the working man. He declares that there is no such thing under the British constitution as absolute ownership of anything, and that the employers forget that legally they are only stewards to whom the nation has entrusted the control of industry, and threatens them with confiscation. As to this we may observe that there is no basis for the assertion that the nation ever entrusted the employers with the control of industry. The men risked their savings in building up these great undertakings, to the great advantage of the community, when they might equally well have placed their capital abroad. As regards the question of confiscation, it has to be observed that the attempt to appropriate and carry on engineering works in Italy, dispensing with the owners, utterly failed, and the men were glad in the end to ask the proprietors to resume control. All recent experience has confirmed that of the past, as to the falsity of the statement which has sometimes been made—that the workmen are able to do for themselves "all that by which money makes money." The co-operative societies, for example, have never founded a new industry or originated any important improvement in methods of manufacture or distribution. In normal times, at any rate, all great creations of wealth can be traced to some one individual genius.

In spite of the official disapproval of violence, there have been some bad outbreaks at Sheffield, which have caused the closing down of additional works. It is difficult to conceive what possible advantage can arise from this to the men's side. The more men out of work the sooner the dispute is likely to end in the breakaway of the men from the unions. Some foolish people, indeed, are advocating a general strike, oblivious of the fact that there has not been in all history a single instance of success thus attained. But ardent and enthusiastic visionaries are always prone to disregard the experience of the past.

As a result of a conference at Barrow on Saturday between the mayor and the trade union leaders with regard to the engineering dispute, it was agreed that the unions affected should be allowed to appoint men for peaceful picketing, on condition that the unions should hold themselves responsible for the conduct of the pickets. Messrs. Vickers have agreed to open three gates at their works, and the men are not to march in procession or assemble in numbers in Barrow or Walney Island in the neighbourhood of the works whilst the men are entering or leaving. Subject to this condition, the imported police are to be withdrawn from Barrow.

On the application of the Chief Constable, the Lincoln magistrates on Saturday issued a warrant for the arrest of four men for alleged intimidation. The Chief Constable said the names of the men were at present unknown, but he had a good description of them. They called at the house of an engineering employee in his absence, and, it was alleged, told the relatives what would happen to him if he continued going to work. The Chief Constable added that he intended to put a stop to acts of intimidation and molestation of workmen and their families in the city, and he hoped the magistrates would assist him.

A lock-out is threatened in the cotton trade owing to the refusal of operatives at two mills at Royton and Middleton to abide by the terms of the Oldham standard lists.

THE STRENGTH OF TIMBER.—A committee of the American Society for testing materials of construction, which reported in 1921, states that the strength of timber is a function of the time of application, the resistence to loads suddenly imposed and rapidly removed being much greater than to slowly applied or static loads.

THE EASTERN DISTRICT OF THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—Arrangements have been made for members to visit works in progress in the Willesden district on May 26 next. The place of meeting is the Town Hall, Dyne-road, Kilburn, and the time 10.30 a.m. Amongst the works to be inspected are some which are being carried out by "distress labour," including the Park Royal surface-water drainage scheme, the North Circular road at Brentfield, and a culvert 6 ft. in diameter under the Midland and South-Western Joint Railway, near Gladstone Park.

10-H.P. SLEEVE-VALVE MOTOR-CAR ENGINE.

CONSTRUCTED BY THE VULCAN MOTOR AND ENGINEERING COMPANY (1906), LIMITED, SOUTHPORT.

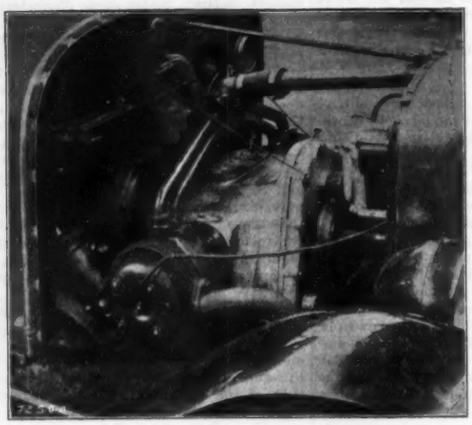


FIG. 1.

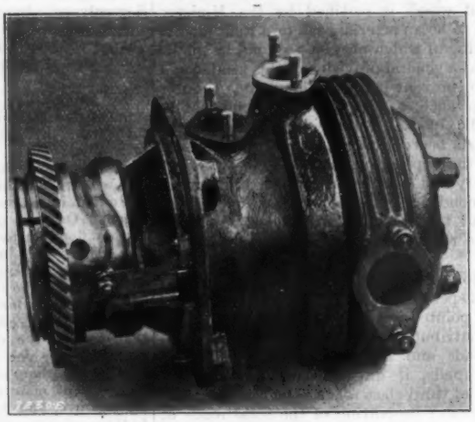


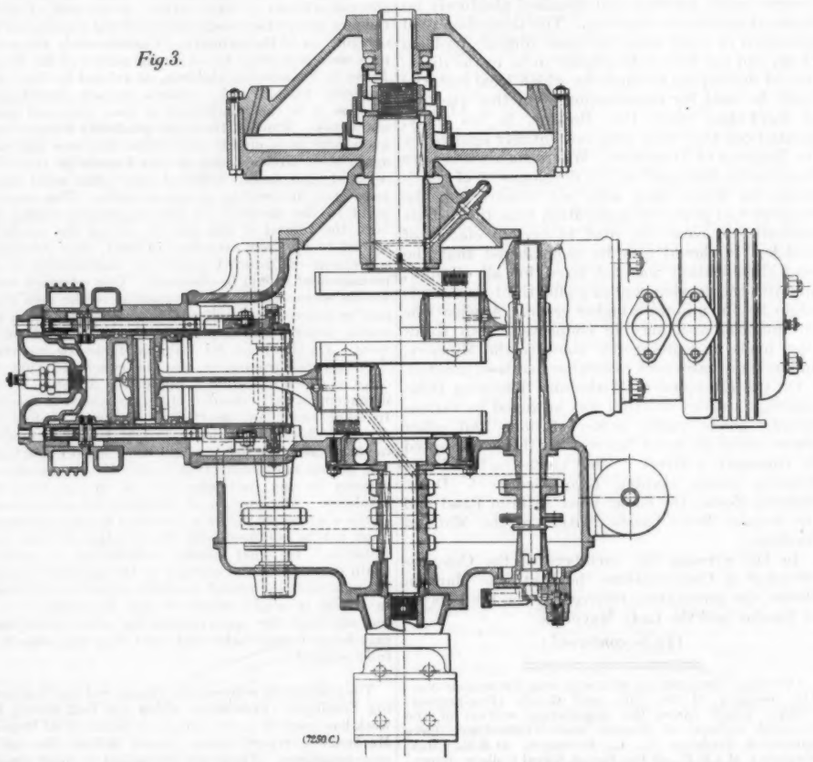
FIG. 2.

OF a new form of sleeve-valve motor-car engine, which has been brought out by the Vulcan Motor and Engineering Company (1906), Limited, of Crossens, Southport, illustrations are annexed. It is of the two-cylinder horizontally-opposed type, with a bore of 90 mm. and a stroke of 110 mm. At 2,000 r.p.m. the engine develops 18 b.h.p. The novel features of the engine are the valve gear and sleeve valve, which are best shown in the cross-section given in Fig. 3. The gear is located at the bottom end of the cylinder and is completely enclosed in the crank-case, the cylinder end carrying a cam which is attached to a worm wheel. This is most clearly shown in Fig. 2. The worm wheel is driven by a worm carried on a shaft which lies parallel to the crankshaft, and which is in turn driven from the crankshaft by chains, as is indicated in Fig. 3. The rotation of the cam operates two push rods, which carry ball bearings on projecting pins working in the cam groove. This feature will be clear from Figs. 2 and 3. These rods, the main parts of which are tubular, as indicated by heavy black lines in Fig. 3, connect to the sleeve valve, which is at the top end of the cylinder.

The valve is cylindrical, and is located inside the cylinder. It is split down a diameter, each half being attached to one of the push rods by two cross-screws, as can be seen at the left hand side of Fig. 3. The screws pass through holes in the head of an internal bolt which fits into the end of the internal push rod. When each half-valve has been set correctly the cross-screws are locked by screwing up this bolt. Slots are formed in the cylinder to allow of the necessary movement of these cross-screws as the valve operates. The valve has no junk rings, and its correct adjustment to the cylinder bore is obtained with these cross-screws, the internal pressure in the cylinder assisting the half-valves to make a tight joint on the working face. The splitting of the valve obviates any distortion which might occur owing to errors in machining if a solid valve were attached to two rods.

In the position shown in Fig. 3 the piston is at the top of its stroke and the valve is in its neutral position. As will be seen the piston is close up against the valve, but the relative movements of the two, of course, prevent fouling. The timing is so arranged that the valve begins to move down to open the inlet port when the crank has turned 23 deg. past top dead centre, the piston having then moved $\frac{1}{16}$ in. on its downward stroke and clear of the valve. The valve has four ports, giving a large port area. These uncover the inlet and exhaust ports in the cylinder as required, the cylinder ports communicating with two circular manifolds which surround the cylinder as shown in the figures. The cylinders are of cast-iron and are water cooled by thermo-syphon circulation. The heads are loose. The crank-case is a one-piece aluminium casting with a loose cover over the timing chains. The crakshaft is drilled for forced lubrication to the big ends, main bearings and chain drive, the oil supply being obtained from a gear pump. The induction system is heated by the water circulation from the cylinder to the radiator, a Zenith carburettor being used with which a consumption of 40 miles to a gallon has been obtained. Ignition is by means of a coil and distributor driven from a Rotax dynamo which provides sufficient current for an electric starter and lamps.

Fig.3.



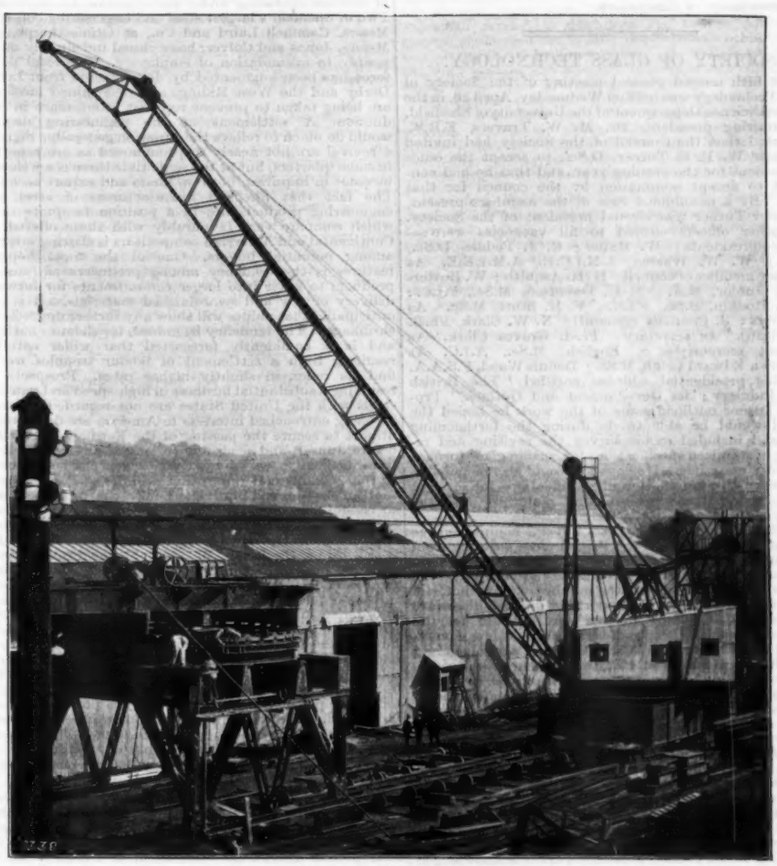
3-TON "TOPLIS" HORIZONTAL LUFFING STEAM CRANE.

IN the view on the opposite page we illustrate a 3-ton steam crane of 100 ft. radius fitted with "Toplis" patent horizontal luffing gear and balanced jib, recently supplied to the Fullers' Earth Union by Messrs. Stothert and Pitt, Limited, of Bath. The work that this crane is called upon to do is of rather a special nature, requiring an exceptional length of jib to give a long outreach and a great height of lift, but at the same time requiring the wheel pressures to be kept as small as possible. Its work is to remove the ground from the right-hand side of a quarry to the opposite side. In the undisturbed ground are layers of Fullers' earth which are, in places, found down to a depth of about 60 ft. below the surface. These have to be uncovered, and the Fullers' earth removed, the waste material being banked on the left-hand side. The angle of repose of this soil being very small, a crane of long radius is needed to keep the pile clear of the track. The excavations may reach 20 ft. below the crane track, and after the Fullers' earth has been removed, the ground is again made up to the level of the track, which latter is transferred so that the crane has then to run on made-up ground. Due to moisture and the pressure of the crane, this ground is liable to fall away towards the working face and fill up the excavation where the work is proceeding, hence the need for making the wheel pressures as light as possible.

The conditions imposed have been met by the crane, and the following are its leading particulars. Lifting capacity 3 tons at any radius between 45 ft. and 100 ft. at a speed of 200 ft. per minute. The load can be luffed between these limits at the rate of 120 ft. per minute, and is fitted with the "Toplis" horizontal luffing gear, which, with the aid of the moving ballast

3-TON "TOPLIS" HORIZONTAL LUFFING STEAM CRANE.

CONSTRUCTED BY MESSRS. STOTHERT AND PITT, LIMITED, ENGINEERS, BATH.



box at the back of the crane, balances the jib and load in all positions. So accurately is this balancing effected that we understand the luffing gear pinion was taken out of gear at the test and the brake released, leaving the barrel entirely free. This was done both with the load on and off, at both maximum and minimum radii, but in each position the luffing barrel remained motionless, proving the accuracy of the balance with or without the load. The travelling speed is 150 ft. per minute. The motions of lifting, luffing and travelling are operated by a pair of horizontal engines, 10 in. diameter by 14-in. stroke, supplied with steam from the boiler at 100 lb. per square inch.

The slewing is effected by a separate set of engines, 7 in. diameter by 10-in. stroke, which drive by means of spur and bevel gearing a steel pinion which engages with a pin rack fixed to the top of the truck. A friction-slipping device is fitted to this gear to prevent excessive shocks from coming on to the crane. All motions are provided with brakes worked from the driver's stand which is in the front left-hand side of the crane house. The house is made of corrugated iron sheets on a steel angle frame. A large window is provided in front of the driver's position, and another in the roof above to enable him to see his load in all positions. The truck is made very rigid by means of steel-plated sides, and in order to distribute the load each corner is provided with a four-wheeled bogie so arranged that all the four wheels shall have equal loads. The track is made to a gauge of 20 ft., and the overall length of the wheel base is 29 ft. to the centres of the end wheels of the bogies. The jib is 130 ft. long, which enables the hook to be lifted 100 ft. above the rail level at any radius. The crane is fitted throughout with self-oiling mild steel pulleys of the "Lawrence" patent type.

"THE USE OF PARAFFIN FOR COAST LIGHTING."

TO THE EDITOR OF ENGINEERING.

SIR,—Our attention has been called to the article entitled "Developments in the Use of Paraffin for Coast Lighting," published in your issue of May 5.

We should like to make one or two corrections in the said article. Your correspondent says that "the first attempt in this country to apply this system of lighthouse illuminant was in the middle of 1900, when Mr. Arthur Kitson brought to the notice of the Trinity House his oil burner using an incandescent mantle." The writer goes on to say that "this burner, which was of the type where an overhead vapouriser enclosed in a hood screen was heated by the flame over the mantle below, was installed in the Lowestoft lighthouse and did not prove itself capable of practical adoption, with the result that Sir Thomas Matthews then developed on the Kitson principle a new burner," &c.

The Kitson incandescent oil system was first brought to the attention of the lighthouse authorities by the well-known lighthouse engineer, Mr. J. R. Wigham, M.I.R.A., who read a paper before the Royal Dublin Society in November, 1900. Mr. Wigham said: "Recent experience has shown that the electric light is not the best light as a lighthouse illuminant; sea captains and other competent judges having testified that it is misleading in clear weather and absolutely useless in foggy weather." He then asked: "Can we find a light with the intensity of the electric light without its defects for lighthouse purposes?" "The new light which I am about to describe is one which seems to possess that desideratum. It is also rich in the red and yellow rays in which the electric light is deficient, and it has besides the necessary volume which contributes to the power of making itself visible in foggy weather, and has also the uniform steadiness not attainable by the electric arc light. This light is an American invention, and is called after the name of its inventor 'the Kitson light.'" It was Mr. Wigham who first adapted the Kitson light to lighthouses in this country, as described by him in the paper referred to. It was some time after this that Mr. Matthews (now Sir Thomas Matthews) wrote to Mr. Kitson for an interview which led to the Trinity House authorities taking up this system. Mr. Matthews stated that it was the policy of the Trinity House authorities to manufacture their own apparatus as far as possible, and as he wished to have his name connected with this light, which promised to supersede all others for lighthouse purposes, an arrangement was made by which the Trinity House authorities were allowed to manufacture these burners exclusively for their own use under Mr. Kitson's patents, and the first installation was made at Lowestoft with most excellent results so far as the light was concerned. A demonstration was given at which Sir Ralph Knox (then the Under-Secretary for War), Admiral Stuart, Mr. Matthews and Mr. Kitson were present, and it was shown that the light could penetrate a mist for a very considerable distance, in fact distinct shadows were shown on the end of Gorleston Pier 8 miles distant in spite of the mist.

The so-called "Matthews Burner" was merely a slight variation of the original Kitson design, but with the facilities possessed by Trinity House Mr. Matthews was able to make his burners of a much stronger character.

But some years prior to this, Mr. Kitson's light was used experimentally for lighthouse purposes in America. As far back as 1896 a trial was made in one of the lighthouses on the Potomac River, the results of which were highly satisfactory. A full account of this invention is given in the "Encyclopædia Britannica," Volume 31, under the heading "Petroleum," from which the following is an extract:—

"As early as 1885 Mr. Arthur Kitson attempted to make a burner for heating purposes on the foregoing principle, that is, by injecting oil under pressure from a fine tube into a chamber where it would be heated by the waste heat escaping from the flame below, the vapour so produced being made to issue from a small jet under the pressure caused by the initial air-pressure and the expansion in the gasifying tube. . . .

"It was not until 1897 that the perfecting of the Welsbach mantle enabled this method of consuming the oil to be employed. The Kitson lamp has given results which certainly ought to ensure its future success, the only drawback to it being that it needs a certain amount of intelligent care to keep it in good working order, but where this has been forthcoming, the lamp has more than fulfilled the high expectations formed of it."

About the year 1895 or 1896 the United States Government appointed a commission to enquire into the origin of this invention of incandescent oil lighting, and after two years of investigation they awarded priority of invention to Mr. Arthur Kitson.

We have no doubt that the above facts will be read with interest by many of your readers.

Yours faithfully,
The Kitson Engineering Company (London), Ltd.
JAMES JACKSON, Secretary.
Stamford, Lincs., May 9, 1922.

GROUND GEARS.

TO THE EDITOR OF ENGINEERING.

SIR,—As engineers are at present very much interested in ground gearing, we think your readers would like to have our views respecting a statement on the above subject made in your issue of April 21. In the article "Mass Production in Gear Cutting," the following information is given: "Grinding with formed wheels is not to be considered since they are inconsistent with the degree of accuracy obtained by generation." This statement is wholly misleading as to the work we are doing in gear grinding. We have been engaged for more than ten years on "mass production" gear grinding work, confined wholly to the grinding of hardened gear teeth with the "formed" wheel. We have ground hundreds of thousands of gears, principally for motor car gear boxes.

The same system of grinding, *i.e.*, using the "formed" wheel, is now being applied to finish grinding the teeth of hardened pinions and gears 30 in. in diameter and up to 8 in. face. These special high duty gears are of particular interest at present to the engineer who has to use high duty gears for speed reduction in electric traction work. A further use for the ground gear is found in engine timing gears, where extreme accuracy of tooth form is necessary to quiet running.

The ground spur gear, whether hardened or not, with straight teeth, can be used in many places where the helical gear is now adopted. It is much cheaper than the helical gear, it will stand a severe service with heavy loads and at high speeds, as the teeth are ground after hardening. When desirable the gear can be made from heat-treated material with extraordinary physical properties. This is but a brief outline of the work undertaken by this company. The process, however, is of wide industrial application where no other gear but one of superior accuracy can be used.

Yours very truly,
FOR THE GEAR GRINDING COMPANY LIMITED,
H. F. L. ORCUTT,
Managing Director.
Anne-road, Handsworth, Birmingham,
May 11, 1922.

"REMEDY FOR SHRINKAGE IN WORLD'S OVERSEA TRADE."

TO THE EDITOR OF ENGINEERING.

SIR,—"What is wrong? This is wrong: that a broad-gauge industrial system is held up and cannot move because of out narrow-gauge money system. Wealth must slow down to pass through the narrower gates of money, because there is more wealth than there is money to move it, and money itself must slow down to pass through the still narrower neck of gold, because there is more money than there is gold to validate it."

My attention has been drawn to letters addressed to you under the above heading, one by Mr. A. Bigland, M.P., which appeared in your issue of April 21, another by Mr. James Adamson on May 5. The quotation I have used from the *Dearborn Independent*, of January 28, is contained in Mr. Adamson's letter, and I agree with him that it describes most aptly the position to-day.

It is easy to agree with Mr. Adamson when he says: "Any standard of value based upon gold, silver or other substance, is liable to fluctuate with the amount of money in circulation," but when he goes on to say: "and hence

is no standard at all"—I suggest, with great respect, that we are asked to prescribe a remedy for the shrinkage in the world's oversea trade, and not to discuss a matter of scientific nomenclature. Let us agree that a measure of length, capacity or weight is a real standard measure, and that the measure of value is not in the same sense a measure at all. We all know what we mean when we say gold or silver is the standard—the measure of value.

Mr. Adamson could, no doubt, if he would, tell us how the volume of money circulating in any country should be controlled, but how does he propose to adjust international balances if gold and silver are no longer to be made available for this purpose?

We require two things in our currency:—

1. That it will be a convenient medium of exchange between different countries.

2. That it shall be a fair and permanent record of obligations over long periods of time.

A debt contracted at one period in exchange for a given amount of average wealth should be, and can only be, justly discharged at another period, if the value or purchasing power of the money remains the same.

Mr. Bigland, if I understand him correctly, condemns our gold standard system:—

1. Because gold is not available in sufficient quantity to support a reasonable amount of currency under a gold standard sound money system.

2. Because gold alone as the standard of value in England does not enable us to obtain a steady rate of exchange with silver-using countries even under the most favourable conditions.

Mr. Bigland speaks of silver and gold having been used jointly between 1814 and 1873; as a matter of fact both metals had full legal tender power in England for 150 years before 1814.

In my opinion, Mr. Bigland's argument is perfectly sound. He does not advocate a change from gold to silver as stated by Mr. Adamson, but the full use of both silver and gold as legal tender standard money at a ratio, and I see no reason why the ratio, if a reasonable one, somewhere in the neighbourhood of 20 to 1—once established by agreement with France, Germany and the United States of America, should not remain fixed indefinitely.

The theory of the fixed ratio turns wholly upon the possibility of substitution. The trade of the world cannot expand if prices are allowed to fall to, or below, pre-war level, as the burden of debt would then become intolerable. Sound money based upon gold alone means low prices, stagnation and insolvency. Sound money based upon gold and silver jointly will, in my opinion, bring back prosperity. When gold and silver are converted into money neither of them can fall in value as commodities below the value of the money into which they are coined.

Both metals vary in production, but this will not affect the ratio; both being legal tender, each having the power to cancel debt, the metal most easily obtainable will be used, and the demand for gold and silver respectively will be such as to maintain that ratio at the point at which it is fixed by international agreement.

I am, dear Sir, yours faithfully,

WILLIAM SMELLIE.

Tower Building, 22, Water-street, Liverpool,
May 15, 1922.

DIE CASTINGS OF ALLOYS FOR FINE MECHANICS.

WHEN the use of alloys, both of the heavy metals lead, tin and zinc, and of light metals, for making finished castings of parts of meters and of other instruments was discussed at Berlin in connection with a paper by K. Kaufmann, of the FertigGuss Gesellschaft (*Zeitschrift für Metallkunde*, January last, pages 8 to 22), so many admissions of troubles with these castings were made by the lecturer, as well as by other manufacturers and professors, that one might feel doubtful as to the reliability of these alloys, some of which were "war substitutes." The discussion dealt in particular with die-casting prepared by forcing the fused alloy by a piston through a hole into the metal mould. But sand castings of the same alloys are also in use, and some of the "Spritzgusslegirungen" are undoubtedly promising. Thus the ample analytical detail of the various alloys given during the discussion will be of considerable interest.

The long-known castings of tin-lead alloys are not strong, have low melting points and must not be heated above 100 deg. C. subsequently, but they shrink little and keep their exact dimensions. Pure zinc is not suitable; alloyed with tin, or with copper or aluminium, it answers; but tin and aluminium do not go together in general; tin foil containing more than 0·2 per cent. of aluminium may crumble in a few days; in complex alloys of zinc and aluminium the influence of tin is less clear. Zinc-tin alloys (for the mouthpieces and horns of telephone apparatus) should not be varnished at temperatures above 150 deg. C., lest a tin alloy sweat out in beads. The Siemens Company exhibited a great many specimens of alloys, essentially of zinc-aluminium, both sand and chilled castings, which had failed, cracked, expanded or shrunk and had become distorted. The Al percentages varied between 2 and 70 in these products, which contained also copper, lead, and sometimes tin. It was mentioned that in America the use of alloys of Al-Zn, with medium Al-percentages had been abandoned by some firms. Some new alloys are treated with acids to produce a fairly non-corrodible surface. Ageing processes are advisable, and purchasers should receive full instructions as to use and be informed also as to the date when the goods were cast and after what period they might safely be mounted. That, of course, might preclude the utilisation of hastily-ordered parts. One zinc alloy containing 4 per cent. of copper, 1 per cent. of aluminium and 8 per cent. of tin, and particularly the new durolith, the composition of which was not stated, were said to give full satisfaction as to strength, hardness and constancy of dimensions.

SOCIETY OF GLASS TECHNOLOGY.

THE fifth annual general meeting of the Society of Glass Technology was held on Wednesday, April 26, in the Applied Science Department of the University of Sheffield. The retiring president, Dr. M. W. Travers, F.R.S., intimated that the Council of the Society had invited Professor W. E. S. Turner, D.Sc., to accept the office of president for the ensuing year, and that he had consented to accept nomination by the council for that office. By a unanimous vote of the members present, Professor Turner was elected president of the Society. The other officers elected to fill vacancies were:—As vice-presidents: W. Butler; C. J. Peddle, D.Sc., F.I.C.; W. W. Warren, A.M.I.C.E., A.M.I.E.E. As ordinary member of council: H. H. Asquith; W. Butterworth, Junior, M.A.; J. H. Davidson, M.Sc., F.I.C.; F. W. Hodkin, B.Sc., F.I.C.; V. H. Stott, M.Sc. As treasurers: J. Connolly (general); N. W. Clark, Ph.B. (American). As secretary: Fred. Graves Clark. As assistant secretary: S. English, M.Sc., A.I.C. As auditors: Edward Leigh, M.Sc.; Dennis Wood, F.S.A.A.

In his presidential address, entitled "The British Glass Industry; its Development and Outlook," Professor Turner outlined some of the work he hoped the council would be able to do during the forthcoming year, and included in his survey the revising and re-issuing of standard specifications for certain glass-furnace refractory materials. He hoped it would also be possible to consider the formulation of specifications for some of the more important glass-making materials, and the setting up of standard tests for glass itself.

Professor Turner then gave a very comprehensive account of the growth of the British glass industry from the time of the Roman occupation to the present day. Speaking generally, there was a steady growth up to the year 1875, after which time the number of glass factories began to decrease and the imports of finished glassware increased. This steady decline was arrested on the outbreak of war in 1914, and during the last few months of 1914 and 1915 there was an infusion of new blood and the industry was revived. Certain new branches of the industry had under the stress of war to be created—the production of chemical glassware had to be undertaken and the building up of a lamp-working industry had to be begun. These new branches of the industry grew to such an extent that during the last twelve months of the war period more than 2,000,000 pieces of chemical glassware were made at the furnace, more than 39,000,000 lamp-blown articles were made and more than 1,000,000 lb. of glass rod and tubing were drawn. During this same period the output of electric lamp bulbs was in excess of 43,000,000, while in pre-war years the output was not more than 4,000,000 bulbs.

Turning to the future, Professor Turner acknowledged that the immediate outlook was not cheerful, but claimed that the industry was much more efficiently equipped than at any other time in its history, and provided that politicians could settle the problem of international exchanges before it was too late, they might look forward to a prosperous future. There was plenty of scope for new developments in the industry, and many novel uses to which glass may be put, so that there was no need to lose confidence in the industry.

The Very Reverend W. Foxley Norris, D.D., Dean of York, gave an interesting address on the mediæval glass of York Minster. He pointed out that the windows of York Minster were the finest examples of the thirteenth and fourteenth century English stained glass that it was possible to find, and they were literally a priceless possession. Unfortunately the glass was showing signs of decay, and in some cases the deterioration was very pronounced. The work of cleaning the windows and releading them was proceeding, and they were also trying various means of preserving the glass itself from further decay.

In the evening the annual dinner was held at the Royal Victoria Station Hotel, Sheffield, at which Professor W. E. S. Turner, the new president, presided.

INTERNATIONAL BALL BEARING STANDARDS.—The American Sectional Committee on Ball Bearings is taking action to establish an International standard for ball bearings. Ball bearings are used more extensively in the United States than in any other country, due to their general use in automotive vehicles. They are also being used in increasing number, however, in industrial machinery. The first ball bearing standards were established by the Society of Automotive Engineers in 1911, S.A.E. standards having been established subsequently for all the types and sizes of bearings generally used. These standards are now adhered to by all American makers of ball bearings, the manufacture of odd-size bearings being limited to special applications. As the export of automobiles by American manufacturers has become of more importance, steps have been taken to obtain International standardisation of bearings so that bearings made by companies situated in other large ball-bearing producing countries would be interchangeable. The American Sectional Committee on Ball Bearings has reported in favour of certain proposals tentatively agreed to by the German and Swedish Ball-Bearing Committees. These proposals will necessitate certain changes in the S.A.E. standards, but only in sizes which are used to a very limited extent.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Work on existing contracts is considerably hampered by the increased activities of gangs of rowdies operating under the direction of extremists. Two of Sheffield's largest steel and engineering concerns, Messrs. Cammell Laird and Co., at Grimesthorpe, and Messrs. Jonas and Colver, have closed indefinitely owing mainly to intimidation of employees. The local police force has been augmented by detachments from Leeds, Derby and the West Riding, and determined measures are being taken to prevent terrorist interference in production. A settlement of the engineering dispute would do much to relieve the situation generally. Signs of a revival are not nearly so pronounced as are reported in some quarters, but at the same time there is a welcome increase in inquiries, both on home and export account. The fact that Sheffield manufacturers of steel and engineering products are in a position to quote rates which compare very favourably with those offered by Continental and American competitors is stirring interest among potential buyers. One of the most hopeful features is the tendency among producers of finished products to enter into larger commitments for forward delivery of raw and semi-finished materials. It is not anticipated that values will show any further appreciable shrinkage. The tendency is, indeed, for them to harden, and it is confidently forecasted that wider activity resulting from a settlement of labour troubles would find its reflex in slightly higher rates. Prospects of resuming a substantial business in high-speed and crucible steels with the United States are not regarded as rosy. Strongly entrenched interests in America are doing their utmost to secure the passing of the Fordney Tariff Bill before June 1, and according to special advices received from Sheffield's steel envoys the best that can be expected is that commercial opposition will be so strengthened that an election will intervene before the promoters are successful. In finished steel a fair volume of business is being done by India and Australia, though with other markets deliveries are mostly of small parcels. India is still by far the largest buyer of Sheffield-made tyres, axles, springs and rolling-stock, but a fact of depressing significance is that the principal inspector of Indian railway orders in Sheffield has gone to Sweden for a period in order to supervise contracts diverted to that country. Revival in products for automobile engineering is slow but sustained. The tool trades are still working from hand to mouth. An apparent revival in engineer's tools was nipped in the bud by labour dislocation. The light foundries are busy on stove grate work and products for municipal housing schemes, but are not able to see far ahead. Sheffield Tramways Committee are considering an offer made by Messrs. Steel, Peech and Tozer, Limited, to increase a supply of steel rails from the contract quantity of 200 tons to 500 tons and reduce the price by 1*l.* to 11*l.* 10*s.* per ton.

South Yorkshire Coal Trade.—House coal pits have reduced their output to meet the diminution in the demand arising from the advent of warmer weather. Sales of best quality fuel to buyers in this area and in metropolitan district are maintained at a healthy level, but there is a big surplus of inferior grades, which are obtainable at cheap rates. Merchants are not augmenting reserves, anticipating a reduction in quotations. The improvement in business in steam hards for shipment is more than maintained, but, apart from railway requirements, the home demand is distinctly easy. Cobbles and nuts are a poor market despite recent price reductions. Special bargains are to be had in smalls. Quotations:—Best branch handpicked, 38*s.* to 39*s.*; Barnsley best Silkstone, 34*s.* to 36*s.*; Derbyshire best brights, 32*s.* 6*d.* to 34*s.*; Derbyshire best house, 26*s.* to 28*s.*; Derbyshire best large nuts, 24*s.* to 26*s.*; Derbyshire small nuts, 16*s.* to 18*s.*; Yorkshire hards, 23*s.* to 24*s.*; Derbyshire hards, 21*s.* to 23*s.*; rough slacks, 10*s.* to 12*s.*; nutty, 7*s.* 6*d.* to 8*s.* 6*d.*; smalls, 2*s.* to 4*s.* 6*d.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Sales of Cleveland pig-iron to home customers are few and small, and dealings with Scotland have almost ceased, but Continental trade is somewhat better, and good inquiries are still circulating for low phosphorus and low sulphur iron for America. Stocks are low, and any sudden material increase in demand for Cleveland pig-iron might be difficult to deal with. Only five furnaces are at present producing Cleveland iron, and though a good deal of idle plant is ready for re-kindling, some little time must elapse before relighted furnaces could be tapped. Small odd sales of Cleveland pig-iron to Scotland are on the basis of 96*s.* 8*d.* f.o.t. Grangemouth for No. 3. All other business with customers at home and abroad is conducted on the usual terms of f.o.t. makers' works, or f.o.b. Tees. Quotations stand:—No. 1 and siliceous iron, 95*s.*; No. 3 G.M.B., 90*s.*; No. 4 foundry, 87*s.* 6*d.*; No. 4 forge, 85*s.*; and mottled and white, 80*s.*

Foreign Ore.—New business in foreign ore is hardly heard of, dealings being confined to transactions in odd cargoes, but imports to the Tees in fulfilment of old contracts, many of which are long overdue for delivery, are on an exceptionally heavy scale, and indeed May unloadings promise to exceed 200,000 tons. Best rubio is 27*s.* c.i.f. Tees, and up to 23*s.* 6*d.* c.i.f. Tees is named for good Mediterranean ores.

Hematite.—Home demand for East Coast hematite has shrunk considerably, and buying for local consumption is now on a very moderate scale; but such events are compensated for to no small extent by larger and

steadily increasing foreign trade. Germany is still the best customer, but fairly extensive negotiations with other foreign countries are reported. Supply of hematite, however, is a good deal more than ample. Some makers are asking 97*s.* for Nos. 1, 2 and 3, but purchasers for home purposes can be made at 96*s.*, and buyers report that they experience no difficulty in placing export orders at 95*s.*

Coke.—Though the position as regards coke is undoubtedly easier, local consumers needing early supplies are reluctantly compelled to pay up to 28*s.* for medium blast-furnace Durhams' delivered.

Manufactured Iron and Steel.—Little new is ascertainable concerning finished iron and steel, but certainly the general situation is no worse. For some descriptions of steel just a slightly better inquiry is noticeable. The reduced railway rates which become operative on Monday next should assist progress towards renewal of activity. Producers are prepared to enter into export contracts at substantially below the following rates, which they adhere to for home trade:—Common iron bars, 12*l.*; iron rivets, 14*l.*; medium steel billets, 8*l.* 5*s.*; hard steel billets, 8*l.* 15*s.*; steel boiler plates, 14*l.* 10*s.*; steel ship, bridge and tank plates, 10*l.* 10*s.*; steel angles, 10*l.*; steel joists, 10*l.* 10*s.*; heavy steel rails, 9*l.* 10*s.*; fish plates, 14*l.* 10*s.*; black sheets, 12*l.* 5*s.*; and galvanised corrugated sheets, 15*l.* 15*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—The position of affairs in the steel trade of Scotland has altered very little during the past week, and while there is a shade more doing there is a great want of life, and enthusiasm is absent. Everybody seems to be waiting on the return of the engineers to their work, and the majority of people feel that even that will give the necessary fillip to trade. In the meantime no orders are being given out beyond those for actual requirements, which is a big handicap to the steel producers. Inquiries are again fair, but little business is expected to result so long as industrial conditions remain so unsettled. In the black steel sheet trade there has been almost no change, but a number of foreign orders of one sort and another have been booked. These, again, do not make up a very heavy tonnage, but always mean that a certain amount of employment is assured. Prices show no variation this week and are as follow:—Boiler plates, 14*l.* per ton; ship plates, 10*l.* 10*s.* per ton; sections, 10*l.* per ton; and sheets, ¼ in., 11*l.* 15*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—The makers of malleable iron in this district all complain of the poor response to the recent reduction made in price. Odd lots have been picked up, but no indication has been given by buyers of any desire to enter the market in the meantime. The general inquiry is a shade better, but it is actual business which is wanted, and that is extremely scarce at the moment. Prices are without change, and are based on "crown" bars at 11*l.* per ton, delivered at Glasgow stations, and the export price is round 10*l.* 15*s.* per ton.

Scottish Pig-Iron Trade.—It is some considerable time now since the Scottish pig-iron trade had anything decent in the way of orders, and makers are looking forward anxiously to a revival in demand. There seems little chance of that taking place, however, until the present labour disputes have been settled. The outlook in that direction is again more hopeful, but until an actual settlement is reached business will continue to be transacted within very narrow lines. The reduced number of furnaces in operation is still able to cope fully with the current demand. In hematite iron there is a little more life, due to the re-start in the shipyards, but no immediate revival in demand is anticipated just at present. The price is called 5*l.* 5*s.* per ton, delivered at the steel works. Quotations for foundry iron are likewise without change at 4*l.* 17*s.* 6*d.* per ton, for No. 1, and 4*l.* 12*s.* 6*d.* per ton for No. 3, both loaded into trucks at makers' yards. A few lots are going through on export account, but the tonnage is small.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—The reduction of the flat rate on coal transport from 4*d.* to 3*d.* per ton by the railway companies from Monday next is not considered sufficient to benefit the Welsh coal trade to any extent as the distances from pit to port are so short that the colliery companies will derive a very insignificant benefit from the concession. Railway rates are still from 85 per cent. to 100 per cent. above the pre-war level, and must be further reduced before they can have any appreciable influence in reviving trade. Both in volume and value the Welsh coal trade suffered a set-back in April. The official figures show that foreign shipments from the four leading ports amounted to 1,748,799 tons, or 401,089 tons less than in March, while the value of such exports amounted to 2,127,134*l.*, a reduction of 414,023*l.* This diminution was, however, not due to any slackness in trade, but to the fact that there were only 22 working days in April, against 27 in March. On the average the April shipments realised about 8*d.* per ton more than in March, for large steams averaged 26*s.* 8*d.* compared with 25*s.* 10*d.* in March, and steam smalls 17*s.* 11*d.* against 17*s.* 9*d.* per ton. Small steams shipped from Cardiff averaged 17*s.* 9*d.* per ton in April, compared with 17*s.* 7*d.* in March, throughs 21*s.* 5*d.* against 20*s.* 11*d.*, and large 27*s.* 2*d.* against 26*s.* 3*d.* Anthracite large exported from Swansea averaged 33*s.* 1*d.* against 35*s.* 10*d.* in March, and smalls 20*s.* 9*d.* against 19*s.* 6*d.* Exports of coal as cargo in the past week amounted to 553,000 tons, which is the highest figure reached for any similar period since the war. The increase was mainly due to the fact that no less than 132,800 tons was despatched to South America and Brazil, which total establishes a record for several years past. The activity of the South American market is doubtless due to the American miners' strike and the greater dependence of the Argentine on South Wales for supplies. Meanwhile prices on the coal market are steadily upheld round the levels which have been prevailing for the past few weeks. While actual business is rather restricted tentative inquiries are numerous. For instance, Germany is inviting tenders for about 50,000 tons of large coal, Russia is asking offers for 60,000 tons, South America wants 35,000 tons and Chile 50,000 tons, with delivery in each case over the next three or four months.

Iron and Steel.—The Welsh tin-plate market has developed a weaker feeling, and at present is in a very depressed state. In fact, unless new business of a substantial character is forthcoming in the near future it is expected that some of the mills will have to close or go on short time. The weakness is believed to be due to the fact that merchants holding supplies are realising. In April exports of tin plates totalled 36,055 tons, against 13,667 tons in the corresponding month of last year. Prices are round 19*s.* 3*d.* for standard boxes.

DIESEL ENGINES AT THE SOUTHEND POWER STATION.—Messrs. Belliss and Morcom, Limited, have recently installed six Diesel engines at the generating stations belonging to the Corporation of Southend-on-Sea. The engines were removed from surrendered German submarines, and the cost under the conditions prevailing at the time was about one-half that of new plant. The aggregate rating of the six engines is 2,500 kw. They were thoroughly overhauled, reconditioned and modified by Messrs. Belliss and Morcom before being put in place. The engines proved of great value during the coal strike last year. They are, moreover, much more economical than the existing steam-driven units, which are small reciprocating sets.

DEATH OF MR. C. G. ROBERTON, O.B.E.—We greatly regret to have to report the death of Mr. Charles G. Roberton, O.B.E., of Messrs. Vickers, Limited, Barrow-in-Furness, which occurred on the 1st inst., after an illness of only one week. Mr. Roberton obtained his early training in Glasgow, but went to Barrow thirty-two years ago, entering the marine drawing office of the old Barrow Shipbuilding and Engineering Company, Limited, an undertaking which was later on merged in Messrs. Vickers, Limited. Mr. Roberton specialised in the design of internal-combustion engines as applied not only to submarines, but to some of the largest oil-driven vessels afloat. During his long connection with Messrs. Vickers, Limited, he came into touch with a great number of engineering experts from the British and foreign Admiralties and various shipping companies, and, in addition to his wide knowledge of engineering matters, being gifted with a genial nature, he had made a host of friends, from many of whom expressions of sincere condolence have been received by his wife and family. His loss is keenly felt not only by the Vickers firm, but also by his many business associates.

THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—The forty-ninth annual general meeting of the above Institution will be held at the City Hall, Cardiff, on June 21, 22, 23 and 24, 1922. The secretary states that as hotel accommodation at Cardiff is very limited early arrangements should be made by those intending to attend the meeting. The following papers will be read and discussed: (1) "Town Planning and Re-planning in Great Britain," by Mr. H. H. Humphries, M.Inst.C.E. (Member), City Engineer, Birmingham; (2) "Town Planning and Re-planning Abroad," by Mr. Thomas Adams (Hon. Member), Town Planning Adviser, Commission of Conservation, Canada; (3) "The Mechanical Equipment of a Municipal Works Depot and Scavenging and Cleansing Department," by Mr. F. Wilkinson, M.Inst.C.E. (Member), Engineer and Surveyor, Willesden Urban District Council; (4) "The Mechanical Equipment of a Highways Department," by Mr. A. Dryland, M.Inst.C.E. (Member), County Engineer, Middlesex; (5) "Mechanical Transport," by Mr. Thomas Molyneux, M.I.Mech.E., Chief Mechanical Engineering Assistant, City Engineer's Department, Liverpool; (5a) "Electric Vehicles for Municipal Work," by Mr. R. B. Mitchell, M.I.E.E., Electrical Engineer to the Glasgow Corporation; (6) "Heavy Oil Fuel Lorries for Refuse Collection," by Mr. G. Bertram Hartfree, F.S.I. (Member), Borough Surveyor and Engineer, Godalming; (7) "The Mechanical Equipment of Waterworks," by Mr. G. R. Collinson, B.Sc., A.M.Inst.C.E. (Member), Water Engineer, Swansea Corporation; (8) "Cardiff Housing Schemes—Organisation and Realisation," by Mr. B. Price Davies, M.S.A., Chief Assistant, Housing Department, Cardiff; (9) "City of Cardiff Waterworks, Taff Fawr Section, Breconshire." Description by Mr. C. H. Priestley, M.Inst.C.E. (Member), Waterworks Engineer and Engineer-in-Chief New Works. On Thursday, June 22, there will be trials and demonstrations of sweepers, road tarring machines, gritters, concrete mixers, electric vehicles, stone breakers, &c., and a kinematic exhibition of other plant will be given in the Hall of the South Wales Institute of Engineers. The annual dinner will be held at the City Hall on the evening of the same day. Visits have been arranged to various works in progress and other objects of interest.

NOTICES OF MEETINGS.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, May 19, at 8 p.m., at Caxton Hall. Lecturette, "Engineering Business in China," by Mr. F. W. G. Clark, A.M.I.Mech.E.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 19, at 9 p.m., Sir William Bragg, K.B.E., D.Sc., F.R.S., M.R.I., on "The Structure of Organic Crystals"; Saturday, May 20, Professor O. W. Richardson, D.Sc., F.R.S., on "The Disappearing Gap between the X-ray and Ultraviolet Spectra. (II) Photoelectric Methods."

THE INSTITUTE OF PHYSICS.—Tuesday, May 23, at 5 p.m., at the Rooms of the Royal Society, Burlington House, London. Annual General Meeting, at which Sir J. J. Thomson, O.M., F.R.S., will deliver his Presidential Address.

THE ROYAL SOCIETY OF ARTS.—Wednesday, May 24, at 8 p.m.: Ordinary Meeting, "The Natural Power Resources of Ireland (Coal, Peat, Water Power)," by Mr. George Fletcher, Department of Agriculture and Technical Instruction for Ireland. Sir George T. Beilby, LL.D., F.R.S., Director, Fuel Research Board, Department of Scientific and Industrial Research, will preside. Friday, May 26, at 4.30 p.m.: Indian Section, Sir George Birdwood Memorial Lecture, "Indian Painting and Muhammadan Culture," by Sir Thomas W. Arnold, C.I.E., D.Litt., M.A., Professor of Arabic, School of Oriental Studies. The Right Hon. Viscount Peel, G.B.E., Secretary of State for India, will preside.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, May 25, at 6 p.m., Annual General Meeting (Corporate Members and Associates only), at the Institution Building, Savoy-place, Victoria Embankment, W.C. 2.

THE ILLUMINATING ENGINEERING SOCIETY.—Thursday, May 25, at 8 p.m., the Annual Meeting will be held at the House of the Royal Society of Arts (John-street) Adelphi, London, when the Report of the Council for the past session will be presented, and the Presidential Address will be delivered by Sir John Herbert Parsons, C.B.E., F.R.S.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, May 26, at 8 p.m., at Caxton Hall. Lecturette, "Engineering Appointments and How to Get Them," by Mr. J. Cameron Rennie.

THE INSTITUTE OF METALS: NORTH-EAST COAST LOCAL SECTION.—Friday, May 26, at 7.30 p.m., in the Electrical Engineering Theatre, Newcastle-on-Tyne. First General Meeting. Paper by Mr. O. Smalley and Mr. S. G. Homfray, on "Some Problems in a Brass Foundry."

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 26, at 9 p.m., a discourse will be delivered by Mr. W. E. Dalby, B.Sc., F.R.S., M.Inst.C.E. The subject is "The Internal Combustion Engine: Its Influence and its Problems." Afternoon Lectures, at 3 p.m.: Tuesday, May 23, Mr. William Bulloch, M.D., LL.D., F.R.S., on "Tyndall's Biological Researches and the Foundation of Bacteriology" (The Tyndall Lectures) (Lecture II); Wednesday, May 24, The Very Rev. William Ralph Inge, D.D., on "Theocracy. (I) Theocracies in General"; Saturday, May 27, Sir Hugh Allen, M.A., Mus.Doc., on "Early Keyboard Music" (Lecture I) (Musical illustrations by Mr. Harold Samuel.)

THE LATE PROFESSOR H. M. HOWE, A DISTINGUISHED METALLURGIST.—The sad news has just come through from America that one of the best-known figures in metallurgical circles has passed away in the person of Professor Henry Marion Howe, University of Harvard, and Professor Emeritus of the Columbia College, New York. His lifelong devotion to the science of metallurgy has made his name a household word in his own country, Great Britain and the Continent. His father and mother were both celebrated persons, the father, Dr. Samuel Gridley Howe, many years ago being amongst the first and foremost in assisting the Greeks to freedom and independence. The mother, Mrs. Julia Ward Howe, was the authoress of the famous Battle Hymn of the Republic. Professor Howe's integrity and honesty of purpose made his scientific, technical and educational work of special value to the world in which he moved. Nothing of doubt was ever allowed to pass his scrutiny. In the world of scientific metallurgy he stood almost unrivalled. Amongst his many contributions may be specially mentioned his great work on "The Metallurgy of Steel," which appeared at a most opportune time, and without doubt greatly helped to develop the science of metallurgy, which was then emerging from its comparatively chrysalis state into the well-ordered branch of science which it now occupies. He was also the author of innumerable papers on metallurgical subjects. In 1895 he received the Bessemer gold medal of the Iron and Steel Institute, and the Elliot Cresson gold medal of the Franklin Institute of Philadelphia, also a special prize and gold medal from the Société d'Encouragement pour l'Industrie Nationale, and, finally, in 1917, the John Fritz gold medal, which honour was shared by our countrymen, Lord Kelvin in 1905, Sir William White in 1911, and last year, Sir Robert Hadfield. He also received several foreign orders, including the Chevalier of the Legion d'Honneur, France, and the order of St. Stanislaus, Russia. Professor Howe was a Fellow of the American Philosophical Society, and the American Academy of Arts and Sciences. He not only took an interest in metallurgy on the scientific side, but was also greatly instrumental in assisting in the practical development and introduction of manganese steel into the United States.

NEW SERVICE RESERVOIRS FOR THE METROPOLITAN WATER BOARD.

MR. H. E. STILGOE, M.INST.C.E., CHIEF ENGINEER.

(*For Description, see Page* 612.)

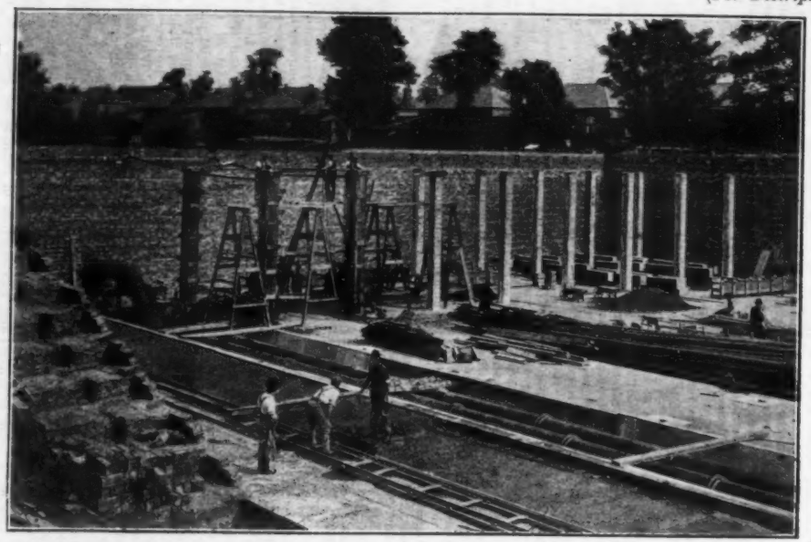


FIG. 20. ELTHAM RESERVOIR: ROOFING COLUMNS AND FLOOR IN COURSE OF CONSTRUCTION.

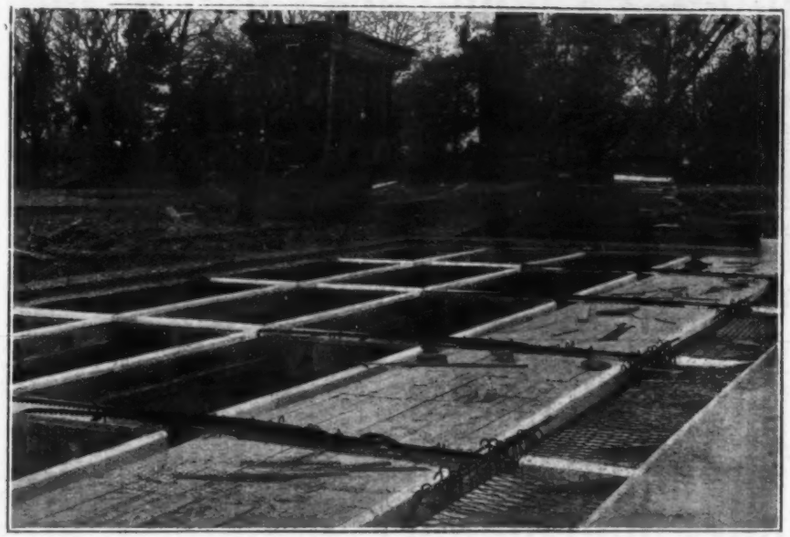


FIG. 21. FARNBOROUGH RESERVOIR: CONSTRUCTION OF REINFORCED CONCRETE ROOF.

FIG. 22. INTERIOR OF FARNBOROUGH RESERVOIR.

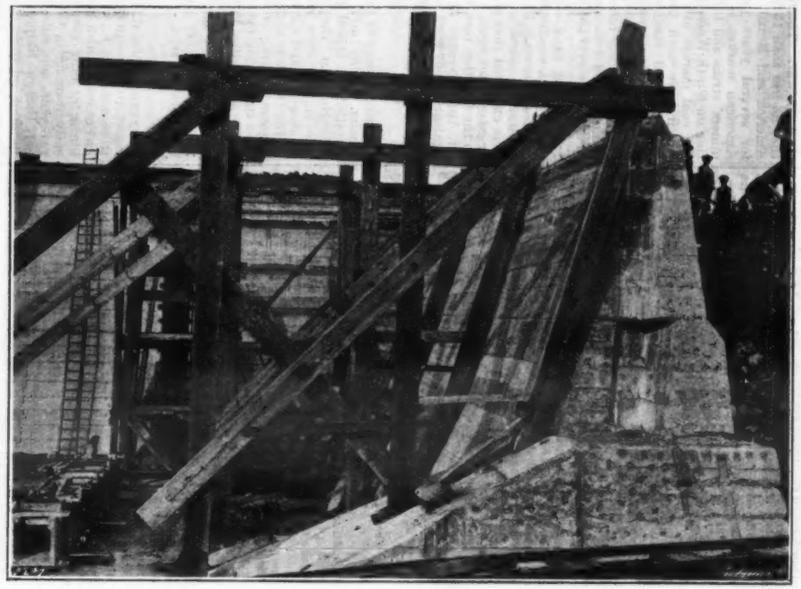


FIG. 23. SECTION OF WALL OF BROMLEY RESERVOIR.

ENGINEERING.

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ENGINEERING.

FRIDAY, MAY 19, 1922.

THE ENGINEER-IN-CHIEF OF THE FLEET.

THE announcement of the retirement of Engineer Vice-Admiral Sir George Goodwin, K.C.B., LL.D., from the post of Engineer-in-Chief of the Fleet, and the succession of Engineer Rear-Admiral Robert B. Dixon, C.B., with concurrent promotion to the rank of vice-admiral, is an event of more than passing interest. In the first place it is appropriate that the work done by Sir George should be acknowledged, and in the second place that the appropriateness of the new appointment should be recognised. Sir George Goodwin became Engineer-in-Chief in June, 1917, on the retirement of Engineer Vice-Admiral Sir Henry Oram, K.C.B., who had held the position since 1907. As Sir George had, however, served as deputy Engineer-in-Chief during the whole of Sir Henry's term of office, he has been either immediately associated with or actually in control of the engineering policy of the Navy for a period of fifteen years. As Sir Henry Oram's retirement took place during the war, when circumstances prevented any reference being made to questions of naval developments, the present occasion is appropriate for reviewing the field of naval engineering, and the important changes that have taken place under the *regime* of these distinguished officers.

The fifteen years under review constitute an important landmark in naval engineering from more than one aspect. The steam turbine had, in 1906, with the completion of H.M.S. Dreadnought, established itself as a reliable prime mover for the largest warships, and in the adaptability of this type of engine to develop large powers a new era had developed. The naval engineers were very proud of the large powers of 15,000 i.h.p. per shaft obtained in the cruisers of the "Good Hope" Class with reciprocating engines, but experience with such large engines had only too plainly indicated that this type of steam engine was approaching the possible limits in size and power that could be relied upon to give uniformly satisfactory results from all points of view. The steam turbine opened up a new field, and rapid advances began at once to be made.

Already, in 1907, warship machinery of 41,000 s.h.p. were under construction, and in 1909 the design of the "Lion" Class of battle crusiers, the machinery of which developed over 70,000 s.h.p., was put in hand. This increase of more than 100 per cent. (compared with the highest powers on service prior to 1907) in the total power installed in one vessel in a period of a few years is noteworthy. It was hardly foreseen at the time of their construction that these vessels would form the striking arm of the Grand Fleet some years later, commencing in 1914, and the fact that these vessels performed brilliant service in this capacity and proved themselves superior in speed and maintenance of power as compared with vessels of a similar class, of later date and under more adverse conditions, shows that the difficulties attending the installation of such large powers had been accurately foreseen and overcome.

Concurrently with the design of larger relative powers in other classes of ships, active development had proceeded in the Navy in the use of oil fuel. The practical difficulties attending the satisfactory burning and application of this fuel have been overcome by the zeal and ability of naval engineers. The actual application to vessels on a large scale was, however, in 1907 and for some years, limited owing to the dependence of this country on overseas supplies. This problem of course still remains. It undoubtedly gave a deal of anxiety during the war, but measures had been taken to cope with the exigencies of such a situation as far as could possibly be foreseen. With the coal-burning installations it was very early realised that the large powers possible with the turbine were tending to be restricted in warships by the large weight and space in the ships necessitated by boilers in which coal was the principal fuel. The purely oil-fired boilers were therefore fitted for some years in torpedo-boat destroyer craft only, as in these vessels considerations of high power with minimum of weight and space occupied, were of the greatest importance. The experience in this class of vessel, commencing with the "Tribal" type which began their trials in 1907, was however sufficient to establish definitely the enormous superiorities of this type of fuel for other classes and, but for the supply difficulty, it is certain that we should not have waited till 1912 before its application to capital ships. In this year the battleships of the "Queen Elizabeth" Class were designed in which this fuel alone is used. The power in these ships is 75,000 s.h.p., as compared with 23,000 in the Dreadnought designed some seven years earlier. It must not be overlooked, however, that general developments had permitted the design of the large battle cruiser Tiger, with oil still as an auxiliary fuel, and in which 108,000 h.p. was developed. This vessel, with the exception of the 70,000 h.p. cruisers of the "Hawkins" Class, was the last of the high-speed warships to be fitted for coal-burning and the whole of the battleships, battle cruisers, light cruisers and torpedo-boat destroyers in the post war fleet are oil-driven, with the exception of the cruisers referred to, and in which for special reasons coal-burning generators in one boiler room were retained. In the design stage of the most modern battleships in commission, viz., the "Royal Sovereign" Class, coal and oil were both arranged for, but this was changed before construction had advanced.

In 1910, Sir Charles Parsons, who had been experimenting for some years to solve the problem of the adaptation of the high-speed turbines for low-speed ships, fitted the first set of mechanical reduction gearing in the cargo steamer Vespasian, and those in control of the engineering policy of the Navy at once saw the possibilities of such reduction gearing, even for high-speed ships, and, taking a very bold step which, as events showed, was fully justified, very early adapted it for powers up to 11,000 h.p. per shaft in torpedo-boat destroyers, and up to 20,000 s.h.p. per shaft in light cruisers.

During the period of the great war those at the head of the Engineering Department of the Fleet had necessarily to cope with a situation of great difficulty, and often under unfavourable conditions. With the large war programmes developed, accompanied as they were by acute questions in relation to *personnel*, shortage of supplies and the maintenance of the sea-going fleets in efficient condition, the greatest courage, resourcefulness and ability, coupled with ripe experience and mature judgment had necessarily to be exercised. This period was one of unexampled strain, and the fact that the machinery of the vessels of the Navy, which was subjected to wear and tear far exceeding anything

ever anticipated, came successfully through this period, says much for the work of the officers, upon whom devolved the higher technical responsibilities. Mechanical gearing, which had hardly passed the experimental stage, became a necessity if best possible results were to be obtained in the circumstances, but again the foresight given to its application enabled it to be developed for powers not thought possible at the time, and as a culmination it was eventually applied up to 36,000 s.h.p. per shaft in the battle cruiser Hood and three other vessels, which latter, however, were not completed. The power in the large destroyers of the flotilla leader type rose to a total of 44,000 s.h.p. with this type of machinery.

Quite apart from a general increase in powers and the problems of building on a large scale, the period called for the design of novel types of vessels, which in many cases presented special engineering difficulties. As a particular case, may be cited the large and fast steam submarines of the "K" Class. During this period the application of the heavy oil internal-combustion engine for much higher powers than had previously been contemplated, called for serious consideration, and although presenting great difficulties for naval work owing to the weight of these engines, progress has been made, and is still being made, in certain directions in their application other than in submarines. That this engine has never been seriously neglected by the Navy as some critics may at times imply, is made evident in Sir George Goodwin's paper on the development of Diesel engines for naval purposes, recently read before the Institution of Shipbuilders and Engineers of Scotland, and which we printed in full in a recent issue (page 535 *ante*). The light high-speed internal-combustion engine has also been successfully adapted for naval use in the vessels of the coastal motor-boat type.

One of the present important responsibilities of the Engineer-in-Chief is that of the efficient training of the officers and *personnel* in charge of, or operating, the machinery of warships. This question has always received great attention by Sir George and, as may be testified by those who have come in contact with him on these matters, his sound judgment and accurate realisation of the needs of the service have always been a valuable asset. Towards the end of his tenure of office he has been active in arranging for the training of officers in engineering, conditions having shown the necessity for a modification of the scheme obtaining during the last twelve years. The great interest he has taken in this question and his knowledge of sound educational principles are well illustrated in the recent address given by him at the Hartley Institute, Southampton, in which the desiderata of the training of an engineer were elaborated.

Sir George has at all times considered it his duty to see that the engineering side of the Navy has been represented, and naval engineering matters kept well to the fore in the discussions arising at the meetings of technical societies. On the Council of the Naval Architects and as president of the Institute of Metals for two years, he has displayed special activity in this direction, to mention only prominent instances. That these activities will not cease with his retirement is shown in his having accepted the presidency of the Institute of Marine Engineers for a period commencing in September next.

Although as regards new construction the position for the last year or two has been somewhat one of stagnation, the responsibilities of the Engineer-in-Chief at the present moment are of no light nature. With the reductions in *personnel* and the urgent demands for economy, the position calls for peculiar abilities in seeing that efficiency and progress are maintained. In spite of the great developments that have taken place in the last few years, the situation is ever one of progress, and never have greater problems presented themselves to be solved than at the present time. In one direction we have seen the adoption for large powers of the turbo-electric system of propulsion in the large vessels of the United States Navy, the merits of which have to be seriously considered in this country. The internal-combustion engine makes rapid strides in the commercial world, and presents an ever more interesting problem as regards its adaptability for warships which only energetic experiment and research will solve. The possibilities of developing the internal-combustion turbine have also to be borne in mind. Under previous *regime* and during the war, it was made apparent that the Navy had its own special difficulties to solve, and the Admiralty Engineering Laboratory was established in 1917, and is still an active concern in which new developments mainly in connection with the high-speed internal-combustion engines are being tested.

Admiral Dixon takes over the position of Engineer-in-Chief therefore at a time when it is essential that an officer with a power to visualise clearly the present position and the future is most necessary. He was a distinguished student of the Marlborough and of the Naval College at Greenwich, and has gained considerable practical experience in important diverse appointments during his career. Leaving the Marlborough in 1888 he became Chief Engineer in 1900 and Engineer-Commander in 1904. Apart from service in several ships, he has held positions at the Admiralty, and was Engineer Manager of Portsmouth Dockyard from 1912 to 1917, being promoted to Engineer-Captain during his tenure of this appointment in 1915. He served from 1917 to 1919 as Assistant to the Director of Dockyards, and became Assistant Engineer-in-Chief in May, 1919, and was promoted to the rank of Rear-Admiral in the same year. In June, 1920, he became Deputy Engineer-in-Chief, which position he now relinquishes to attain the highest position in the engineering branch of the Navy. With such experience behind him there is no reason to doubt that a progressive policy will be maintained, and that British naval engineering will still keep its position in the front rank at a standard which has given it its prestige in the past.

THE OIL SHALE OF ESTHONIA.

THE importance of the oil shale of Esthonia, locally known as kukkersite, is not limited to the new Republic of Esthonia and the adjacent territories. Lecturing upon this shale at the Institution of Petroleum Technologists on May 9, Mr. E. H. Cunningham-Craig, F.R.S.E., F.G.S., characterised kukkersite as the oldest oil shale that is being worked and also as the richest oil shale, apart from the torbanites which are frequently classed with cannel coal. The kukkersite deposits are abundant and they occur under extraordinarily simple conditions. Esthonia is a big, low-level plateau, dropping from a height of about 200 ft. down to the southern shore of the Gulf of Finland, and covered largely by forests and peat mosses.

The exposed strata of the oldest Cambrian, Silurian and Devonian formations have never been disturbed; there are no mountains, and the oil shales, up to 8 ft. in thickness, are quarried in open workings. The layers of oil shale are separated by bands of limestone and do not look like a shale at all. They resemble light, crumbly sandstones, but they do not contain any grains of sand; the shale colour is grey-white to olive green and turns to reddish brown on weathering owing to the presence of iron. About 50 per cent. of the so-called shale is calcite *débris* of fossil trilobites and brachiopods; the density is 1·2 to 1·4, higher when too much limestone is present. The kerogen (the organic matter) is bright yellow. Most of the 30 per cent. of the water of the fresh shale disappears on air-drying for weeks. There is hardly any mud, and apart from the calcite Mr. Cunningham-Craig considered the matrix containing the kerogen as a fuller's earth.

As regards the origin, he severely criticised H. von Winkler's suggestion, that the kerogen was a sapropel, *i.e.*, a structureless jelly of marine algæ, and other views, having himself no doubt that kukkersite was an example of inspissated petroleum absorbed by colloidal inorganic matter. Questioned during the discussion he defined an oil shale in fact as a colloidal combination between colloidal petroleum and colloidal inorganic matter. There is much to be said for this definition, though the shale vanishes. Mr. Cunningham-Craig had thus to indicate a source of the petroleum. He admitted that there was no trace of petroleum in the Cambrian sandstone, but he found some, in the dictyonema shales above it; gas had been met with, moreover, when the Kokskar lighthouse was built, there was an ancient mud volcano on the Island of Oesel, a little oil had been struck on the Island of Dagoe (both islands are West of Esthonia), and a very old manjak (jet-black asphaltite) had been found.

Professor W. W. Watts, called upon to open the discussion, was hardly satisfied with this geological evidence, and was not inclined to dismiss the algæ hypothesis, particularly because Mr. H. Bekker, an Esthonian now working under him, had found evidence of algæ in the kukkersite as well as their modern representative on the Esthonian shore.

Mr. Cunningham-Craig's reply was that, even if the whole shale consisted of algæ, it could not yield more than 35 gallons of oil per ton, whilst the theoretical yield of the kukkersite was 90 gallons, and 70 gallons and 80 gallons had actually been obtained, though the bad vertical retorts in use gave only 50 gallons at the best. The "theoretical" yield was criticised by Professor Brame, president of the Institution, and the high yields were doubted by him and by other speakers. Yields vary, of course, with the conditions of the distillation. On the other hand, Dr. Mollwo Perkin exhibited various oils, containing 0·5 per cent. of sulphur, which he had distilled from 3 cwt. of kukkersite at the rate of 55 gallons per ton, and Mr. Stainer Hutchins had even obtained 90 gallons, when using peculiar retorts with agitators.

Anyhow it was acknowledged, that the 1,000,000,000 tons or 1,500,000,000 tons of kukkersite of a belt of 36 miles by 7 miles in Eastern Esthonia, now quarried by hand for the Esthonian Government, deserve attention. The fines and smalls of the shale are sent to the rotary kilns of Kunda, where they give a white flame. The general question is, however, whether oil shales will be able to compete against free oil. At present, and in oil-producing countries, the position is difficult. In the United States, Mr. Gordon Pitt remarked, much has been done of late in perfecting the methods of oil-shale retorting; yet the position of free oil was too strong, even for Utah shales yielding 60 gallons of oil per ton. Mr. Gordon Pitt thought that suitable retorting combined with immediate cracking, before cooling, promised the best financial return. The discussion thus reverted to the retorting problem, which is not yet solved. Mr. Cunningham-Craig recommended simple, fool-proof, low-temperature retorts. The increasing importance of shale oils at the present time is certainly not underrated even in the United States.

TRADE WITH SWITZERLAND.

SWITZERLAND is among the neutral countries which have suffered the most by the war, and, as pointed out by Mr. J. Picton Bagge, commercial secretary to the British Legation in Berne, in a report recently issued by the Department of Overseas Trade, Switzerland, is at the present time peculiarly sensitive to the lack of purchasing power in Central and Eastern Europe, and to the low cost of productions in countries such as Germany where the internal purchasing power of the currency is out of all proportion higher than its exchange value. In Switzerland, Mr. Bagge states, every branch of industry is suffering; over 20 per cent. of the factory hands are entirely without employment, whilst a further 13 per cent. are only partially employed. There are many industries in the country, industries covering fine chemicals and dyes; the manufacture of woollen, cotton and silk goods, watches, machinery, &c. Taking the engineering trade with which we deal more especially, we find it stated that at the commencement of 1920, there were 53,575 workmen employed by the 178 firms forming the Union of Swiss Machine Manufacturers; at the end of last November 13,000 of these had been dismissed, and of the remaining 40,000 only about 18,000 were fully employed, whilst the remainder were working short time to the extent of 30 per cent. to 50 per cent. Germany, the country's nearest competitor was able to undersell Swiss manufacturers by 70 per cent. At the present moment, the German manufacturers could buy their raw material for one-third and even less, of the price paid by Swiss manufacturers in the world's markets, whilst the German wage-bill was about

one-tenth of that of the Swiss producer. These figures show the gravity of the situation in regard to the Swiss engineering trades, and we greatly regret to read that under the pressure of present conditions there is a possibility of some Swiss industries being transferred to neighbouring countries there being at the same time the emigration of the better workmen. The engineering establishments of Switzerland, as our readers are aware, are among the finest, and their products are known practically throughout the world; this result has been achieved, notwithstanding the distance which separates the country from all shipping ports and in the almost total absence of raw materials of any kind, and it affords evidence of the skill, initiative and business capabilities of the inhabitants. In these circumstances the regret with which the works' owners view the possible transfer alluded to may well be imagined.

The mineral wealth of the country has, so far, been found very small. Anthracite mining was started in the Valais during the war, when coal was very scarce and expensive. In 1920, 74,589 tons of anthracite were raised, as compared to 41,487 tons in 1919, an increase said to be due to improved mining machinery. During 1921, the general crisis in all industries also affected mining, and as a rule the opinion is that coal mining in Switzerland has but small prospect of success. Salt is also mined, and asphalt; the latest figure of export of this latter product was just under 14,000 tons, which compares very unfavourably with the pre-war annual quantity of 50,000 tons.

The total water-horse power available in Switzerland is 4,000,000 continuous horse-power, and on December 31, 1920, there were, inclusive of three Federal railway power stations, 11 power stations in operation, supplying 300,000 h.p. Some of these stations are being extended and five others are under construction, planned to supply 252,000 h.p. Further schemes are contemplated, but in the utilisation of this most important natural resource of the country work is delayed by the high capital outlay involved. The Rhine navigation, between Basle and Strasbourg, with which we dealt in a former article (see ENGINEERING, vol. cxi, page 267) remains an unsettled question, there being still two schemes, one put forward by France proposing the construction of a lateral canal, the fall in the river being turned to account for the generation of electric current, and the Swiss scheme of improving the present bed of the Rhine in the same reach. The matter is still being considered by the International Commission.

The British Chamber of Commerce for Switzerland, at Basle, which was opened in October, 1920, increased its membership, it is satisfactory to note, from 30 to 321 during the first year of its activity. A branch office of the Chamber for French Switzerland is at Lausanne.

It is somewhat surprising that this Chamber of Commerce should have been established comparatively so late in the day, for we find in a very interesting book on "Les Relations Economiques entre la Grande—Bretagne et la Suisse dans le Passé et le Présent," by Dr. William Waldvogel, that commercial interchanges between Switzerland and this country commenced as early as in the 16th century, following the much earlier religious, political literary relations and tourism. The business connections between the two countries from the latter part of the 18th century had reference mainly to textiles and machinery for their manufacture, and several important Swiss establishments which have since specialised in all classes of engineering and electrical work can trace their origin back to these early British connections. The book contains numerous points of interest to the two nations; it states, for example, that a Swiss engineer, Charles Labelye, superintended the construction of the first Westminster bridge, in 1738, receiving an annual salary of 100*l.* plus an allowance of 10*s.* per day. Other Swiss, like Colonel Henri Bouquet and General Sir Frederic Haldimand fought in the British Colonial wars, the latter being for a time Governor of Quebec. A relative of the General, William Haldimand (1784–1862) became a Director of the Bank of England and Member of Parliament.

Information of this nature which covers the past is most interesting, and appeals both to the general reader and to the business man; the latter will also find in the work by the Swiss author statistical and other data calculated to facilitate commercial intercourse between the two countries. Commerce between Switzerland and the United Kingdom gradually increased annually down to 1913, the last complete year before the war, and in the latter year the Swiss imports from the United Kingdom reached a total value of 4,500,000*l.*, the exports from Switzerland to the United Kingdom being 9,400,000*l.*, the latter made up almost entirely of finished products and manufactured foodstuffs. Owing to free trade, Swiss exports to Great Britain in the 10 years from 1892 to 1901 increased by 60 per cent., whereas in the same period the increase was 22 per cent. in the case of the United States, 18 per cent. in the case of Germany and 6·5 per cent. only in that of France. In the words of a Swiss business man established in London, "Swiss manufacturers and merchants work the English market for what it is worth; let our English friends do the same in Switzerland and they will soon find that our countrymen at home are quite willing to place their orders with manufacturers on this side of the Channel." One of the great advantages to Switzerland of the British market—apart from the value it has *per se*—is the facilities which it offers for re-export. During the four years directly preceding the war Germany was the first country in the list in regard to the value of exports to Switzerland, whilst the United Kingdom was the fourth; in the matter, however, of exports values from Switzerland, Great Britain and her colonies and dependencies came first, followed by Germany as second.

To illustrate further the intimate connections which exist down to the present day between this country and Switzerland, reference is made, among other points, to the great work carried out by the late Charles Brown; to the activities of the British companies who work the Swiss asphalt deposits; to the agreement recently made between Messrs. Brown, Boveri and Co. and Messrs. Vickers, Limited; to the business relations established between the Federation of British Industries, British Chambers of Commerce and the Berne Commercial Exchange; to the formation, above alluded to, of the British Chamber of Commerce, to the appointment of a commercial secretary at the British Legation, Berne, all of which, we sincerely trust, will have for effect not only to maintain but also to develop the friendly intercourse which, for centuries past, has always obtained between the two countries. In this, the reports issued by the Department of Overseas Trade and publications such as the one we have thus briefly outlined in the present article will further afford a valuable aid.

NOTES.

GAS MASKS FOR FIGHTING FIRES.

IT is disappointing to hear that the gas masks and canisters, which were developed during the war and which finally afforded protection against almost any poison gas at the front, are not giving much more satisfaction in fighting ordinary city fires and industrial gas escapes than the oxygen-breathing apparatus and other appliances which are successfully used in mines. The mine apparatus fail in the fire brigade service because they are too heavy, they require constant care, and it takes a long time to put them on. On the other hand many complaints have reached the United States Bureau of Mines that men wearing the Army gas masks were overcome by fire fumes. In a New York pier fire it was the sulphur fumes that did the mischief; in Detroit, celluloid and varnish fires proved too much for the masks; in Chicago it was merely the smoke from a burning rag-shop; at Rochester the smoke from a basement was mixed with ammonia from a refrigerating machine and with carbon monoxide from a broken gas pipe. In many cases the gas masks answered, of course. But it was confirmed by experiments (Technical Paper No. 248 of the United States Bureau of Mines, by A. C. Fieldner, S. H. Katz and S. P. Kinney) that the gas masks would stop the sulphur and nitrous fumes, unless too concentrated, and the acrid smoke of smouldering fires, but they could not arrest the carbon monoxide and ammonia. We know by this time in England what to think of the increasing percentages of carbon monoxide in our coal gas, as to which the Board of Trade CO Committee was very tolerant, partly because the CO was said to have done little harm in America. Ammonia is absorbed by some hydrated metallic salts, such as copper sulphate impregnated on granular pumice stone ("Kupramite"); but that salt is useless against other gases. Mixed with silica gel, which is itself a high-grade substitute for charcoal as to certain organic vapours, the sulphate is a useful absorbent for some industrial purposes. But the gel is not very durable, nor generally applicable, and it does not arrest carbon monoxide. When the Bureau warns against the use of gas masks in mines after explosions and in fires smouldering in basements and badly-ventilated places, it thinks particularly of the carbon monoxide. Celluloid burns fiercely, but yields much higher proportions of CO than other bright fires. Some progress has been made in the design of CO canisters since this paper, No. 248, was prepared; some of these which we have noticed rely on the oxidation of the CO, and the deficiency of oxygen in smoky atmospheres is almost as bad as the presence of poison gases. The best general safeguard would, no doubt, lie in oxygen apparatus if they could be made less cumbrous and more convenient. The Army gas mask, we should add, will protect against the vapours generated by the application of carbon tetrachloride fire extinguishers. The vapours of this compound are poisonous, the decomposition yields poisonous vapours of phosgene, chlorine and hydrochloric acid, and the commercial tetrachloride, moreover, frequently contains carbon disulphide; but a good gas mask would absorb all these poisons. For celluloid fires water seems to be the best extinguisher.

THE LONDON COUNTY COUNCIL TRAMWAYS.

According to an official report the loss on the London County Council tramway undertaking during the past year was 79,397*l.*, whilst during the previous year it was 590,580*l.* It does not appear from the report whether the Council is making due allowance for maintenance, the cost of which was very much underestimated at the outset. There can be no doubt but that if the tramways had remained in private hands the Council would have welcomed every attempt to improve methods of transport. Instead of welcoming the motor 'bus because it provides a less obstructive, and therefore quicker and more convenient means of transport than the unweildy tramcar, the Council is not merely protesting against the competition of this great addition to travelling facilities, but is concerned to learn that the Government intend to facilitate the improvement of the tubes where the present congestion is, at certain hours, intense, and could not be effectually relieved by any possible extension of the trams. The committee repeat the statement that the tramway situation would be materially bettered by linking up, but offer no evidence of this. As a matter of fact, such data as are available indicate that any gain would be insignificant. When any course is advocated and supported by opinions instead of by evidence, it is very important that the opinions should be weighed, and as the opinions of the Highways Committee have proved so unfounded as to the profits that were to be derived by the tramway speculation, such opinions should be very heavily discounted now. The report gives statistics as to the relative 'bus and tram traffic on a selected route, from which it appears that save in the early morning, the proportion of passengers who prefer to travel by the more modern means of transport is very much greater than the proportion of the 'bus capacity to the tram capacity on the route. It is possible that special cheap workmen's fares offered during the early hours by the trams is responsible for the slightly greater favour that the trams enjoy at that period of the day. The Council claim credit for the work done by it in maintaining the roadway occupied by its tracks, but if the operation of the trams had been left in private hands, the companies would have had to do the same, so it is difficult to see where the gain to the community

comes in. The old plea is made against overlapping of services. As their own figures prove, the public on competing routes show a preference for the 'buses on account of the better service rendered, but the Council demand that 600 out of the 700 'buses operating along tramway routes should be eliminated, so as to compel the public, at whatever loss of time and convenience, to patronise their out-of-date system. The Council indeed object to the suggestion that tramways are obsolete, and point to the large traffic carried. Obviously, however, such an argument proves nothing. When the steam turbine came in, many power stations carried on effectively for years with reciprocating engines, which generated millions of units annually, but this fact did not make the old type of prime mover any the less obsolete.

THE IRON AND STEEL INSTITUTE.

(*Concluded from page 596.*)

POWER PLANTS.

The President next called on Colonel D. L. Selby-Bigge to read his paper on "Recent Developments in Power Production." In this paper the author drew attention to the immense quantities of low grade fuel and waste gases now unutilised in this country, and said that such high standards of efficiency had been reached in steam turbines and electricity generators, that only comparatively trifling further economies could be realised in the engine room. It was, however, otherwise with the boiler house, where there was commonly a lack of skilled supervision and control. Steam plants at collieries required remodelling, as it appeared that some 7 per cent. of the total coal raised was used under colliery boilers. There were, moreover, three million tons of so-called refuse coal lying at pitheads of which the calorific value was estimated at 5,000 B.Th.U. per lb. The highest thermal efficiency officially recorded for any steam driven station was 17·75 per cent. The cleaning of coal could be effectively carried out by the froth flotation process, in which the waste was crushed to pass a screen of about $\frac{1}{16}$ in. mesh, and formed into a pulp with water. This was subsequently treated in agitation boxes with the addition of a little oil (1 lb. to 1 ton of coal). As a consequence minute air bubbles formed on the coal particles, which caused them to rise to surface in a froth which was skimmed off in a frothing box. The froth contained one part of water to one of coal, and being free from clay or lime filtered readily. In continuous operation 2,000 lb. of dry coal had been obtained per sq. ft. of filter area per 24 hours. The coal as removed from the filter contained 12 to 13 per cent. of moisture. The author claimed that the cleaned product amounted to 98·7 to 99·9 per cent. of the total coal in the waste. The labour cost was 4*d.* per ton. The author next drew attention to the very large boilers installed at the River Rouge works of the Ford Motor Car Company at Detroit, where no less than 276,000 lb. of water had been evaporated from one boiler in one hour, and stated that thirty years ago the maximum steaming capacity of a boiler was 7,500 lb. per hour. Pressures had risen much of late, and several boilers were working with 350 lb. per square inch. When blast furnace gases were first used for boiler firing, the gas was uncleaned, and the efficiency realised not more than 63 to 65 per cent. in normal working conditions. With cleaned gas a more effective type of burner could be used and an efficiency of 73 to 75 per cent. obtained. Waste heat boilers had been constructed which were operated with the waste gases from furnaces. The tubes of these boilers were 50 diameters or more in length and the gases were passed through at high velocities. As they left the boiler the temperature was within 30 deg. C. of the steam temperature. Pulverised fuel had been largely used in America and was rapidly growing in favour in France. At the Lakeside generating station tests made under the auspices of the American Government had shown efficiencies ranging from 86·3 to 89·1 per cent. The Ford plant at Rouge River already referred to was also, the author said, operated with pulverised coal. He added that similar fuel had been successfully used for firing reheating furnaces.

The discussion was opened by Mr. H. M. Ridge, who said that the froth flotation process was of very great importance and made available coal which would otherwise be lost, and it might moreover lead to an improvement in the quality of coke. He thought, however, that efficiency would hardly be attained with the screen of $\frac{1}{16}$-in. mesh mentioned in the paper. The mesh should not be more than $\frac{1}{32}$ in. as a maximum, and was preferably still smaller. This, however, involved an increase in the cost of crushing. Even two years ago, 17 million tons of coal wastes were being treated by flotation He regretted that he could not accept the author's estimate of over 98 per cent. efficiency of recovery. From the author's own figures the speaker estimated that only 55 per cent. of the coal was obtained in the clean product, but this was too low, as much better results were obtained with flotation as applied to colliery dumps. The author's estimate of 4*d.* per ton as the labour cost did not include allowance for royalties or for the cost of crushing which was quite an important item. The speaker called attention to a possible new source of power supply in this country. If the CO_2 from modern lime kilns was passed through producers in place of steam, a gas of high calorific value was obtained, which might prove of considerable importance.

Mr. Patchell said that it was essential to bear in mind that the provision of CO_2 and other recorders in the boiler room would not necessarily ensure efficient operation. What was wanted was better supervision. Large power users sometimes realised this, but many steel works would find that the provision of such supervision would be well worth their while. Some one had said that the chemist was the cheapest labourer you could get, and with this the speaker agreed. The paper required editing. The author had quoted 17·75 per cent. as the best thermal efficiency recorded, but it was important to note that the station with which this record was achieved was very small and was fired with gas, the conditions being quite unusual. The River Rouge plant, to which reference had been made, was part of the blast furnace plant erected to provide the Ford Car Company with iron. It was a very notable undertaking. The works comprised the deepening of the river so that a 10,000-ton boat could swing there. The author had said that the limit of boiler capacity 30 years ago was the production of 7,500 lb. of steam per hour, but the speaker had, earlier than that, put in boilers of twice this output, and long ago superheat temperatures of 700 deg. F. had been reached, but with the reciprocating engines then in vogue could not be utilised, as it was necessary to reduce the temperature to 500 deg. F. before admitting the steam to the cylinders. In his remarks on the utilisation of waste heat, the author had omitted the cost of the fan power, and in one table he had mixed up gauge pressure, absolute pressure, and both Fahrenheit and Centigrade degrees. At Detroit some friends of the speaker had installed larger boilers than those at the Ford works. The rate of evaporation in the Ford tests appeared to be 10·4 lb. per square ft. of heating surface per hour, but whether this was really an economical rate was an open question. In any case boilers were not usually worked at such rates of evaporation. One of the most important factors in the improvement of power station efficiency had been the publication of comparative figures. The Board of Trade had the power to call for such figures, but having obtained them, did nothing with them, but left the task of analysing them to private enterprise. The speaker suggested that the Electricity Commissioners should insist on the production of figures.

Mr. Wick said that the high coal consumption in collieries was due more to the use of old engines situated far from the boiler house than to bad boiler practice. Some of the pits, moreover, would make a better showing if the consumption of coal was referred to the horse-power generated instead of to the total tonnage mined.

X-RAY ANALYSIS OF STEEL.

The next paper taken was entitled "X-ray Studies on the Crystal Structure of Steel," and had as its authors Dr. Arne Westgren and Gösta Phragmen, of Stockholm.

The paper, which we publish on page 630, described the determination of the crystalline structure of iron by means of X-rays. The rays used were the "characteristic" rays of iron itself which were obtained by using a piece of iron as the anti-cathode of the vacuum tube. The research showed that in the β and δ phases the iron had a body centred cubic structure, whilst within the intermediate γ phase it has a face-centred cubic structure. There was thus in the δ-phase, which is confined to a small range of temperature below the freezing point, a reversion to the original type of crystallisation. The lattice system of γ iron was found to be enlarged by the presence of dissolved carbon. Steel containing 0·50 per cent. of carbon when quenched in water from 760 deg. C. was found to be on the verge of being amorphous. A comparison of X-ray photograms taken with cementite and spiegel iron indicated that the structure of the two was identical.

The discussion was opened by Sir W. H. Bragg who said that the paper was of great scientific value. The authors had shown that at high temperatures the iron reverted to the structure of the β or α phases, and continued as if an intermediate γ phase had not been formed. Another interesting point was that the distance between the centres of two atoms were much the same in the whole series. If there was a difference when the structure was face centred as in the α, β, and δ phases, and when it was body-centred, as in the γ phase, he would be glad to know it. The distance between the atom centres was of great importance as it had a bearing on the strength of the material, as was well shown in the case of bismuth and antimony, where with different crystalline structures there was a difference in the distance between the atomic centres and the properties were quite different. He asked whether the dissolved carbon was uniformly distributed, and whether the carbon atoms existed as carbon atoms fitting into interstices in the iron. Did the carbon atoms show any evidence of an independent crystal spacing of their own superimposed on that of the iron? He again called attention to the scientific value of the work done. Researches of this kind had had to be put aside in this country during the war, but Sweden and America had taken the matter up and achieved very valuable results. Since the peace the Department for Scientific and Industrial Research had financed a research on the method of determining crystal structure by the X-ray analysis of powders, and as one result apparatus which could be applied very easily had been evolved. Such researches promised to be very valuable industrially. Indeed, applications had already been made, and he thought it would be commercially advantageous if all the great metallurgical, chemical and dye industries financed further work, and he suggested that the Iron and Steel Institute might set the example.

Dr. W. Rosenhain said that one notable new point brought out was the structure of the δ iron which existed for a short time below the freezing point. It was interesting, but hardly surprising, to learn that this phase had the same structure as α iron. As a matter of fact, however, the metal had not much choice in the way of alternative forms of crystallisation. With respect to the γ phase, he was not sure that he understood what was meant by the statement that in the γ phase the carbon atoms lay in the interstices of the iron. If this meant that the carbon was not really incorporated as a component of the space lattice, but pushed in between it, he thought the suggested arrangement an impossible one. The authors had shown that the γ lattice was enlarged by the presence of the carbon, but this need not imply that the carbon atoms were pushed into the interstices, particularly if the carbon atoms were at the centres of the cubes. He agreed with Sir William Bragg that it would be interesting to search for signs of a regular distribution of the carbon atoms in γ iron, but such a regularity would be equally probable if in the space lattice a carbon atom replaced an iron one. The authors' observations on martensite fitted in extremely well with the facts

discovered by the study of heat treatment from which it appeared that the hardness obtained by quenching and tempering was attributable to the fact that solid solutions had greater solvent powers when hot than when cold. Hence if the cooling were sufficiently rapid there was a separation of minute crystals, which disorganised the whole space lattice from which they sprung. In this way we might get an amorphous phase. In martensite we had minute crystals of γ iron, and perhaps of cementite and also a considerable amount of material the crystalline structure of which had been disorganised.

Professor Carpenter, who followed, said that the facts brought out in the paper fitted in very well with Professor Honda's conclusions. Although quite unaware of the authors' work, Professor Honda had arrived at the conclusion that the structure of the δ-phase was the same as that of α iron. It was now necessary to incorporate the δ-phase into the iron equilibrium diagram and this had been done by Professor Honda.

Colonel N. T. Belaiew said that the results of the authors' work appeared to be that the natural structure of the iron atom corresponded to the α or δ-phase, and that the γ structure was a side issue. He was disappointed to learn that cementite did not crystallise in the regular system. Goniometer measurements of crystals of cohenite found in meteoric iron showed that in this case the crystallisation was on the regular system, and it was natural to believe that cementite had the same structure. He suggested that Dr. Westgren should examine cohenite by the X-ray method.

Dr. Harrison, who followed, said that at the National Physical Laboratory they had got microscopic evidence of a change of structure at the δ point. If steel containing 0·1 per cent. of carbon was overheated, but ultimately raised beyond 1,450 deg. C., and then cooled, the structure obtained was similar to that of normalised steel, so that a refinement occurred at this very high temperature. By the addition of other elements to the iron, he suggested that the γ phase might be entirely eliminated.

Dr. Westgren preferred to reply to the discussion in writing, but said that he wished he had not stated in the paper that martensite was on the verge of being amorphous. What they really found was that the crystals were very minute, but they had not actually proved the existence of amorphous iron.

Inner Structure of the Pearlite Grain.

When the meeting reassembled in the afternoon, Colonel N. T. Belaiew's paper having the above title, was taken. This paper was on the programme for the morning session, but the time available had been insufficient for dealing with it. The author outlined the views explained in detail in the paper, and illustrated his remarks with the aid of numerous lantern slides. The paper, which we reproduce in full in another part of this issue, shows that the arrangement of the cementite lamellæ in a pearlite grain is roughly parallel to one another and to the crystallographic plane of the grain—presumably to one face of the cube. A secant plane perpendicular to that face will be normal to the lamellæ and the angle of inclination ω for that plane will be zero. All the lamellæ of the grain will be seen on the normal plane and the distance between two lamellæ on such a plane will be the actual distance Δ_0. As the angle ω increases, the number of lamellæ seen on a section of the same grain, decreases and the apparent distance between them increases. The graph of natural cosines will show the ratio of decrease in the number of lamellæ, and of the increase in the distance between the lamellæ. It is suggested that Δ_0 may be taken as one of the characteristics of steels, and that values of Δ_0 might be computed to determine various kinds of pearlite and sorbite pearlite. The usual values of Δ_0 met with in practice would be 350 $\mu\mu$ or 300 $\mu\mu$.

The discussion was opened by Dr. H. C. H. Carpenter, who remarked that the Institute should be congratulated on having obtained the paper as the work involved in preparing it had been carried out under by no means ideal conditions. Thanks were due to Colonel Belaiew for having worked out the stereometry of the pearlite grain. The quadrant diagram of a pearlite grain reproduced in the paper, the speaker said, was very useful, and it showed that it was not until an angle of inclination of 60 deg. was reached, that the number of lamellæ was halved. Extreme cases were, however, brought out in other diagrams, which showed sections at 0 deg. and at 84 deg. Colonel Belaiew had been able to push his analysis up to 86 deg., but at angles exceeding 80 deg., measurements became very difficult. The speaker mentioned that Miss Elam and he had recently obtained interesting confirmation with regard to the apparent spacing of lamellæ in accordance with the orientation, and had obtained it with pure metal, viz., vacuum-etched copper; he exhibited a microphotograph illustrating this point. The author's explanation of the apparent curvature of cementite lamellæ in pearlite, viz., that it was bound up with volume changes at the moment of formation, the speaker regarded as a very plausible one, and he concluded by remarking that the paper showed how much could be got out of a geometric study when considered from the point of view of stereometry.

The next speaker, Dr. W. Rosenhain, said that what the author had pointed out was fairly obvious once attention had been drawn to it; it was a question of simple geometry, but its application to pearlite was interesting. If the inter-lamellar distance of pearlite was constant for a given sample of steel, it would provide a means of defining one of the structural constituents which was dependent on its heat treatment. The speaker, however, expressed doubt that the inter-lamellar distance was constant to any high degree of accuracy. It would, he said, be interesting if it were possible, to cut two sections at right angles through some of the grains, and thereby prove the case more fully. That the author's conclusions were broadly correct, the speaker thought was obvious. The author began by giving his idea of the origin of the laminated structure of pearlite, but the speaker said he could not agree with the explanation in the least, and did not think the author had followed it consistently himself, because in one place, he said that the orientation of the pearlite lamellæ followed one of the cleavage planes of the original grain, in which the pearlite was formed, but afterwards showed cementite crystals and suggested that they had exerted a directing influence on the lamellæ. The two might coincide, but it was quite evident that one or the other must be the determining factor. The speaker was inclined to doubt the influence of the orientation of the mother gamma grain upon the pearlite. The author's microphotographs showed that the orientation of the pearlite lamellæ was not constant throughout the original gamma grain. The speaker thought there could be little doubt that with a hypereutectoid steel showing a network, the network roughly showed the gamma structure. Inside the network, however, there was not one orientation of pearlite lamellæ, but several, and these were not geometrically related to each other as they ought to be if they corresponded with the original cleavage of the gamma grain. The explanation, the speaker added, must be sought farther afield, and it must be realised that pearlite was only one of a group of substances having a laminated structure. There were other eutectoids having a laminated structure, and there was a large number of bodies having laminated structures in which there was no previous cleavage orientation to guide the crystals. He had never found any evidence of common orientation throughout the cementite of a pearlite grain, although there was evidence of common orientation of ferrite. What had been observed was that certain metals appeared to exert a dominating influence on the eutectic structures in which they had a part, and what seemed to occur was the crystallisation of one of the two constituents of the eutectic, with the residual space filled in by the other metal. Whether the other metal was orientated either by itself throughout the grain, or with the dominant partner, had not been established. The speaker thought it must be supposed that something similar occurred in the formation of eutectoid from a solid solution, and that alpha iron formed a kind of dendrite in the interstices of which the cementite films found their place. With regard to the curvature, the speaker thought there might be something in the author's explanation, but curved lamellæ, he remarked, were found in eutectic crystals from a liquid. Another point to which the speaker called attention was that when a section was very oblique, slight deviations from perfect planeness became very important, and some of the minor irregularities of the outlines of the cementite, he said, were due to that cause. In some of the microphotographs of oblique sections reproduced in the paper, the edges were very irregular, which, the speaker said, was partly due to the breaking away of the thin edges of the plate, but more particularly to surface irregularities. Another small point of technique was that in taking photographs or examining a finely laminated structure, it made a very great difference whether a half-field illuminator was used or a clear glass disc, since, with the former, the resolving power of the lens was twice as great in one direction as in the other. The speaker concluded his remarks by expressing admiration for the microphotographs with which the author had illustrated his work.

Dr. W. H. Hatfield, who followed, said the members were greatly indebted to the author for the lucid manner in which he had laid the facts before them, and remarked that the paper had greatly enriched our knowledge of the subject. He was, however, in substantial agreement with Dr. Rosenhain as to the mechanism of formation of the cementite plates in a pearlite grain. The speaker greatly admired the author's work which, he said, was accurate as far as it went. He pointed out, however, that the structure was a metastable, and not a final, one, and also that the author had omitted any reference to the effects of surface tension, which brought about an entire rearrangement of the structure.

Mr. J. C. W. Humfrey said that the paper was particularly interesting to him in that it brought out the nature of the pearlite grain. In low carbon steels it was possible to bring out the network structure of crystals by etching, and with high carbon steels, the laminations of the pearlite itself marked out the same boundaries, but with the intermediate steels it was very difficult to bring out the outlines of the ferrite and pearlite crystals. The speaker, however, had found that by heat tinting, instead of etching, the outlines of both could be brought out at the same time. He exhibited some microphotographs of specimens obtained by etching with nitric acid and by heat tinting to illustrate the superiority of the latter process. The speaker added that he had found that the general cause of failure of steel was the breaking of the ferrite lamellæ, and remarked that if the dimensions of the structure could be altered so as to increase the proportion of ferrite to cementite, and also to make the cementite lamellæ very thin, the cementite would undergo very much more plastic deformation than it did in the normal state. The steel would thus adapt itself more readily to conditions of severe strain.

Mr. E. H. Saniter, the last speaker in the discussion, also expressed appreciation of the paper, and said he did not intend to criticise the ground covered. The paper, he said, appeared to introduce a new terror in that it would be possible to specify a heat treatment which would give a definite distance between the lamellæ. He might, however, be mistaken in this view, and he hoped that this was the case.

Colonel Belaiew, who then replied to the discussion, said he had been very much interested in the photographs shown by Professor Carpenter, which were beautiful illustrations of the stepped structure. With reference to Dr. Rosenhain's remarks on the gamma grain and the alpha grain, he thought there was a misunderstanding. What he, the speaker, had said was that if there was a certain grain, say a gamma grain, and if a secondary crystallisation occurred spontaneously throughout the whole volume of that grain, then the secondary deposits would lodge themselves parallel to the four faces of the octahedron. He had also cited another case, namely, that supposing instead of such spontaneous crystallisation throughout the whole of the grain, the crystallisation was as in the pearlite alpha grain, then instead of the spontaneous crystallisation, there would be something of what was seen in pearlite, viz., a deposition of one lamellæ on the

other. He had never suggested that there was any relation in the orientation of the gamma grain, and of all the pearlite grains. He had tried to make it clear that he called the pearlite grain the alpha grain, and on all his slides and pictures he had tried to show that the original gamma grain comprised within itself a very large number of different alpha grains. For this reason he had nothing to dispute in Dr. Rosenhain's remarks, being, in fact, entirely in agreement with him. The speaker also agreed with Dr. Rosenhain that the etched figures on ferrite were a distinct proof of the common orientation of ferrite, but with reference to the remark that no proof that the orientation of cementite lamellæ within a certain grain was exactly the same had been given, he would ask Dr. Rosenhain to examine Fig. 11 of the paper. On that figure there were several lamellæ of cementite, and if the cleavage planes were examined, it became quite clear that all the steps in every lamellæ were running parallel in the same direction; that was one of the points which the speaker regarded as of considerable importance. If the question was whether there was proof that all the cementite lamellæ within a certain grain were crystallographically orientated, he would say that the lamellæ furnished that proof. With reference to Dr. Rosenhain's suggestion that it would be useful to make two sections, he quite agreed that that should be done, but was not sure whether it would be done by himself or by someone else. The object of his paper was to make the relations clear and to ask other contributors to accumulate additional observations. It seemed to him there were two ways to prove what Dr. Rosenhain quite rightly said was the most important point. The first was to select a certain pearlite grain and to make two sections through that grain. In the second method, since the pearlite grains were extremely minute, it would be possible to take a large section containing a very large number of pearlite grains, and on the assumption that in such a section all the possible sections and angles of inclination would occur, instead of making the section through the same grain to apply what might be called the calculus of probability to those grains. The reason he had exhibited slides from various parts of the same alloy and from various parts of different alloys, was to show that when examining a number of pearlite grains, it could be seen that they always followed the same law. With reference to Dr. Rosenhain's remarks on orientation, the excess cementite was influencing the orientation of cementite lamellæ in pearlite, and that was why the slides had been shown; those, however, were exceptional cases. To arrive at definite conclusions, it was necessary to select grains so that the disturbing influence of large masses was not felt. In reply to Dr. Hatfield, the speaker remarked that the reason he did not mention surface tension was that he had endeavoured to avoid reference to what might be called the dynamic stage of the formation of pearlite, which question had been dealt with by Mr. Whiteley and others. He had been interested in Mr. Humfrey's remarks and would be glad to have a detailed explanation of the method of heat tinting referred to. In conclusion, the speaker remarked that the microphotographs illustrating his paper were made by himself in collaboration with Captain Brandt and that the greater part of their excellence was due to the skill of the latter.

DELAYED CRYSTALLISATION IN CARBON STEELS.

The next paper taken was one by Mr. A. F. Hallimond entitled "Delayed Crystallisation in the Carbon Steels: the Formation of Pearlite, Troostite and Martensite." This paper, which we hope to reprint later, deals with the application of the supersaturation theory to steel, and first gives a summary of recent researches on delayed crystallisation and inoculation, after which the origin of pearlite, troostite and martensite is discussed. The area below the eutectoid point, common to the metastable ranges for cementite and ferrite, is termed the eutectoid area and indicates those conditions under which the growth of pearlite can occur. The causes that determine the spacing of pearlite are described. Martensite is regarded as a labile shower of alpha-ferrite, and troosite as a labile shower of cementite. In the latter case, the appearance of the cementite is quickly followed by the growth of alpha-ferrite, due to inoculation by the cementite at a relatively high temperature.

In calling on Mr. Hallimond to present his paper, the chairman explained that it was proposed to discuss it jointly with one by Mr. J. H. Whiteley on the formation of globular pearlite. Mr. Whiteley was, however, unable to be present, and his paper was consequently taken as read. The following is a brief summary of Mr. Whiteley's paper which we also intend to reproduce later:—

THE FORMATION OF GLOBULAR PEARLITE.

The paper shows that the carbide constituent of pearlite does not at once dissolve completely at Ac 1. With coarse-grained hypoeutectoid steel, heating for more than 15 min. was needed at 760 deg. C. (40 deg. C. above Ac 1), to effect a complete solution, and much longer periods are required at lower temperatures. The persistence of the nuclei also depends to a large extent upon the size of the pearlite grain. Increasing the grain size retards solution. On cooling, the nuclei, even if ultramicroscopic in size, inoculate the solid solution at the transition point, and the pearlite so formed is spheroidal, and not lamellar, in structure. The term "globular" is used to designate this type of pearlite. Globular pearlite can be formed in hypoeutectoid steel at a temperature 15 deg C. to 20 deg. C. higher than lamellar pearlite; a certain degree of supersaturation appears to be necessary to produce the latter. The formation of globular pearlite from carbide nuclei within the γ-iron areas offers a method of ascertaining the true equilibrium point Ae, since, in slow cooling, as soon as the metastable region is entered, the nuclei initiate crystallisation of the carbide and ferrite and lag does not occur. By applying this method to a case-hardened steel containing 0·52 per cent. of manganese, the Ae line in the equilibrium diagram was found to be horizontal to within 5 deg. C. As the temperature falls below Ae, the ratio of formation of globular pearlite is slow at first and then increases rapidly until the point Ar 1, at which lamellar pearlite can grow, is reached. The presence of globular pearlite induces an earlier growth of lamellar pearlite in adjoining parts of the solid solution which may happen to be free from nuclei. In hypoeutectoid steels, although the range of temperature above Ac 1 in which the nuclei persist is wider, globular pearlite is not always produced in cooling. In some steels the tendency for lamellar pearlite to form, notwithstanding the presence of nuclei, is very strong. It is suggested that, in hypoeutectoid steels at any rate, the formation of lamellar pearlite only during slow cooling, indicates the entire absence of carbide nuclei from the solid solution.

After Mr. Hallimond had briefly outlined the theory put forward in his paper, the Chairman invited discussion on the two papers and Dr. D. Hanson then rose to make a few remarks on Mr. Whiteley's paper. Mr. Whiteley's results, he said, could be explained more simply and, he thought, more correctly than by the theory the author had given. If a steel were heated above the eutectoid point for a time insufficiently long to ensure complete solution of the cementite, each undissolved particle was necessarily surrounded by a layer of austenite saturated with carbon. The maximum carbon content in this layer, the speaker continued, was a function of the temperature, but it was necessarily greater than that of the eutectoid. Each undissolved particle of cementite in Mr. Whiteley's steels was surrounded, at 750 deg. C., by a layer of hyper-eutectoid steel. The disposition of cementite on the undissolved particles as the alloy cooled was therefore the normal adjustment of the concentration of the phases and was in no way dependent on inoculation of the cementite nuclei. After the eutectoid transformation temperature had been passed, further deposition of free cementite on the existing nuclei might take place, but little or no supersaturation of the austenite was likely to occur, since the presence of both ferrite and cementite in the steel would prevent such super-saturation with respect to either constituent. Supersaturation of the austenite on cooling, the speaker said, was quite usual when the steel had been heated to a temperature sufficiently high to dissolve all the cementite. Separation of ferrite might, therefore, take place without simultaneous separation of cementite for some distance below the eutectoid line. When the transformation of the eutectoid then took place, it was preceded by precipitation of the excess of cementite from the residual austenite, and this cementite formed a fringe round the pearlite.

Dr. W. Rosenhain, who followed, said that as the hour was late he did not propose to discuss the papers at length. The contributions, however, should not be allowed to pass without expressing interest, as they were of considerable importance, work on super-saturation having been too long neglected. The formation of martensite in steel during quenching was an exceptional phenomenon, but that was not the only way in which a hardened structure could arise. Certain alloy steels, when quenched, became softer and could be hardened by subsequent re-heating. The theory of super-saturation, the speaker remarked, might supply an explanation of that phenomenon, and he thought Mr. Hallimond's researches of service in calling attention to the matter.

Mr. Hallimond, the only other contributor to the discussion on these papers, had prepared a written communication, which he read, with the Chairman's permission. This communication, however, dealt with three other papers by Japanese authors, viz., one on the "Constitutional Diagram of the Iron-Carbon System" by Professor K. Honda, one on the "Stepped A 1 Transformation in Carbon Steel during Rapid Cooling," by Professor Honda and Mr. T. Kikuta, and one on the "Heat of Transformation of Austenite to Martensite and of Martensite to Pearlite" by Mr. N. Yamada. As time did not permit the three last-mentioned papers to be taken and the Chairman suggested that they should be discussed by correspondence, we propose to give only that part of Mr. Hallimond's contribution, which had reference to Mr. Whiteley's paper.

Mr. Hallimond said he was glad Mr. Whiteley had adopted the super-saturation theory to account for the effects recorded in his paper, but was unable to follow all of his theoretical conclusions. The true equilibrium point, Ae, the speaker said, was the true eutectoid point in the diagram given in his (Mr. Hallimond's) paper. When the composition varied from the true eutectoid value, we were concerned with two different saturation temperatures for alpha ferrite and for cementite, respectively. The point which would be determined by Mr. Whiteley's proposed method of observing the disappearance or growth of carbide particles in austenite, the speaker said, was a point on the cementite-saturation curve and not the point Ae, there being no reason to suppose that the austenite areas had exactly the eutectoid composition. The cementite curve, the speaker continued, was very steep, and therefore the amount of carbide deposited on the existing particles would be hardly visible, while many of the smallest particles would be absorbed by the larger ones during the period of heating. From the microphotographs reproduced in Mr. Whiteley's paper, the speaker thought it would be agreed that the whole of the carbide in the decomposed areas had been precipitated. We had, in fact, a very convincing picture of the growth of granular pearlite, and it was the starting point of this growth that had been identified with the equilibrium point. The speaker had indicated in his paper that the growth of pearlite consisted essentially of the expansion of an area of alpha ferrite, the rejected carbide being precipitated on the edges of the lamellæ. He suggested that the growth of the pearlite originated with the appearance of a crystal of alpha ferrite by inoculation on the surface of one of the cementite particles at the temperature represented by the point F^1 in the diagram in his paper. Mr. Whiteley's temperature of about 705 deg. C., therefore, represented the value for F^1 on slow cooling, and not the true equilibrium point, which was 725 deg. C. according to Portevin and 726 deg. C. according to Honda for similar steels. The inoculation point, the speaker said, was apparently about the same in all steels when carbide particles were present, but was lower when they were absent. The speaker finally suggested that it should be made clear whether the

terms Ar, etc., referred to the temperature at which the recalescence was initiated or to the maximum temperature attained, and he added that the structures must, in some cases, have developed at higher temperatures than those recorded for the furnace chamber.

At the conclusion of Mr. Hallimond's remarks, the Chairman proposed a vote of thanks to the Institution of Civil Engineers for the use of their hall for the meetings. This was carried with acclamation, and after Mr. Saniter had proposed a vote of thanks to the Chairman for presiding, and the Chairman had briefly responded, the meeting terminated.

THE ROYAL SOCIETY SOIRÉE.

WITHOUT being crowded with exhibits to the extent of some of the pre-war soirées, the first soirée of the Royal Society of this year, held last Wednesday, was of decided interest, especially to the engineer and to the biologists. We shall practically have to confine our present notice to matters touching the engineer, but we should like to point out that the science of the president of the Royal Society, Sir Charles Sherrington, M.D., who is now in his second year of office, was also well represented.

A few exhibits of historical interest claim first mention. The first was a clock, designed by Lord Kelvin, and described by him as a new astronomical clock and a pendulum governor for uniform motion. The clock was given by Kelvin to his sister-in-law, Lady Hargreaves Brown, and was presented to the Royal Society by Sir A. H. Brown in 1919. The clock stands in the entrance hall of the building. In order to retain the simplicity of the Graham dead-beat escapement without the drawback of stopping the whole train of wheels by the pressure of a tooth upon a surface moving with the pendulum, Kelvin reduced the wheel to an arm revolving in the period of the pendulum, which is two seconds for a one-second pendulum, or in some odd multiple of this period. The pendulum may hence execute one or several complete vibrations without being touched by the escapement. The escapement train is controlled by two pendulums, for one second and half a second respectively, the pallets being attached to the bottoms of these pendulums. The arc of vibration of the second-pendulum is half a centimetre, or 0·01 of the radian on each side of the vertical. The winding mechanism of the clock was originally supplied with an 11-ft. drop weight. The Cambridge and Paul Scientific Instrument Company has replaced this by an automatic switch-gear of the type introduced by Sir Howard Grubb for equatorials. The broken glass rod of the pendulum has been renewed by Messrs. Powell & Sons.

The second historical exhibit consists of the original microphones of 1878 and experimental apparatus of the late Professor David Hughes, shown by the Science Museum of South Kensington. The original induction balance was shown by Hughes at the Soirée of 1879; some apparatus for the transmission and reception of radio signals, to which Mr. Campbell Swinton has recently drawn attention, date from the same year. All these devices were made by Hughes himself, and the nails, &c., used in their construction, were mentioned in his descriptions. The microscope of 1896, with geometrical slides of the late Dr. Keith Lucas, equally rough in appearance, was another ingenious historical exhibit contributed by the Science Museum.

As last year, the first item of the catalogue was a demonstration given by Sir John Dewrance and Professor E. G. Coker, on behalf of the Cutting Tools Research Committee of the Institution of Mechanical Engineers. Last year (*see* ENGINEERING, June 17, 1921, page 752), Professor Coker had demonstrated the optical effects by means of which the distribution of stress during the action of turning tools can be studied. The machine used on Wednesday examines and measures the distribution of stress caused by the action of planing and milling tools; in its construction, this machine follows the general features of design recently described by Professor Coker before the Institution of Mechanical Engineers (*see* ENGINEERING, May 5, pages 564 to 569 *ante*); by changing the heads the machine could quickly be modified to watch either planing or milling.

The action of a planing tool appears to be very similar to that of a lathe tool, when this latter is used for turning a disc, and it seemed probable that the stress distribution produced in the material would be somewhat more simple. As will be observed, however, in Fig. 1, where a planing tool is shown in action, the optical effects are much the same as those described for a turning tool.

The colour bands here shown as dark brushes indicate that the stress system is approximately radially directed from the point of the tool. If in fact lines are drawn from the cutting edge in any direction, the stress intensity can be inferred where they cross the bands, since the extreme outer bands mark a unit stress of about 1,150 lbs. per square inch, and each succeeding band reckoning

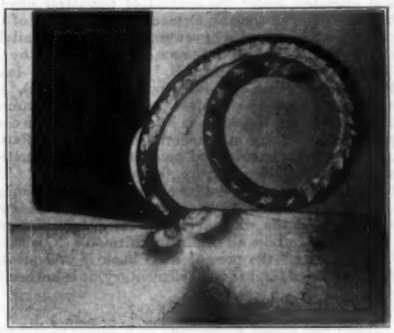


FIG. 1. STEEL PLANING TOOL CUTTING A STRIP OF NITRO-CELLULOSE.

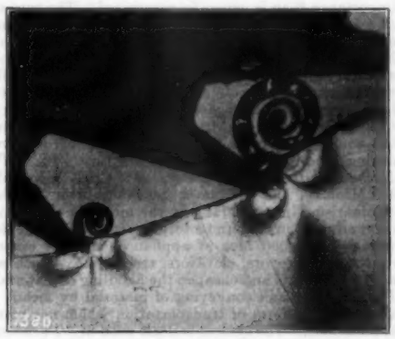


FIG. 2. STEEL MILLING CUTTER OPERATING ON NITRO-CELLULOSE.

inwardly marks a further increase of this unit stress up to very near the intense black, where the material has broken down and no longer obeys this simple relation. Four of these bands are distinctly visible in front of the tool. In this instance the recovery of the optical properties of the shaving is retarded by the further bending action of the upper part of the tool, and it will be noticed that, after finally passing out of contact therewith, the shaving shows very marked optical effects of plastic stress, which finally become very faint owing to further bending action due to coiling up in a spiral with ever-decreasing radius.

The action of a milling cutter is more complicated than either of the cases described above, since there are several cutting edges in close proximity, and the stress effects tend to overlap, especially in the final stages of a heavy cut. The shaving removed is also uniform no longer, but increases in thickness as the cut progresses. This is shown in Fig. 2, where two of the three teeth in operation are shown in action producing shavings of increasing thickness which show, in this case, the characteristic markings of material torn away from the main mass by a wedging-off process with little or no true cutting action. The colour bands observed here appear to have the same general characteristics as those described with reference to Fig. 1; but at the extreme end of this cut the stress becomes very intense, and the two systems of colour bands coalesce and produce a stress system which is probably somewhat complicated, although so far it has not been examined quantitatively.

The next great novelty, the demonstration of some very curious Effects of Alternating Magnetism, by Mr. W. M. Mordey, will certainly arouse great interest among both scientific and practical men, although Mr. Mordy is not yet prepared to explain the phenomena beyond associating them with hysteresis susceptibility, and though the apparently-obvious utilisation of the experiments is still to come.

Paramagnetic materials, as we know, arrange themselves in lines or curves across the pole-gap of a magnet or a direct-current electromagnet; diamagnetic materials place themselves equatorially

Fig. 3.

Fig. 4.

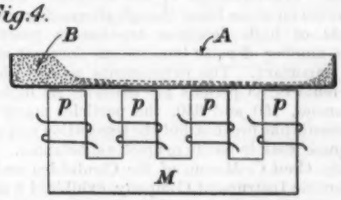
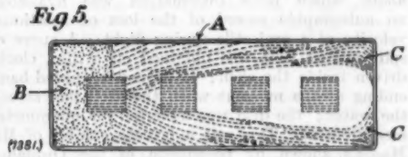


Fig 5.



to the gap. When laminated magnets are excited by alternating currents, these phenomena appear unchanged in ordinary experiments, and the use of alternating-current electromagnets does not seem to offer advantages. But Mr. Mordey observed that the specular hematite (the grey variety of metallic lustre) took up the equatorial position as in Fig. 3, though it is a very feebly paramagnetic material, and that observation led him to further experiments for the demonstration of which he used twelve electromagnet poles, arranged in a row (Figs. 4 and 5 show four), wound for one-phase or for two-phase circuits. Over these poles he placed shallow glass and cardboard troughs containing various magnetic materials in fine or coarse subdivision; the troughs did not cover the whole surface of all the poles, so that end effects could be watched.

With one-phase currents, iron filings (and filings of nickel and cobalt similarly) simply oriented themselves axially, somewhat as with uni-directional fields. When the second phase was also turned on, the particles were moved in three directions, upward, along the axis and sideways, as in Figs. 4 and 5. These figures, however, merely indicate the type of motion; they do not show the charm of the demonstration any more than our diagrams of Professor Coker's experiments suggest the beauty of the colour phenomena. The particles arrange themselves in parallel fins, nearly an inch high, along "planes of force"; these fins are replenished on the left side by particles drawn in, and they send particles to the right, moving at the rate of several inches per second; these migrating particles avoid the poles and collect again at the other end of the trough, where new fins are formed. When the trough is moved across the polar axis, the fins bend over with the motion; when it is lifted up, so that the magnetic field is weakened, the fins collapse,

but the motions continue. Stalloy powder (high-silicon iron) behaved like iron, but was more sluggish. When aluminium filings were used, no effect whatever was observed; that speaks against eddy current effects. When a copper disc, capable of rotating about its vertical axis, was brought up to a pole, half of the disc being over a pole face, the disc began to spin, but the sense of the rotation was the opposite to that of the migration of the magnetic particles; thus eddy currents seem to be ruled out.

Very instructive was the further experiment with specular hematite. When the trough covered three poles, the middle one of which was not excited, the powder marked the square outlines of the two poles and arranged itself also in two intersecting rings about the poles; when the intermediate pole was also excited, most of the material aggregated in the equatorial position of Fig. 3, which would thus be only a special case of the arrangement resulting with closely-adjacent poles. When in other experiments particles of iron, hematite, &c., were mixed with sand, the magnetic particles were driven out of the sand, upwards and onwards, and mixtures of tungsten and tinstone were "concentrated" in the same way, the tinstone (oxide) remaining behind the quickly-travelling tungsten particles. These concentrations can also be effected under water, the buoyancy of which facilitates the movements whilst the surface tension complicates them. Concentration of wet ore-slimes should be possible on those lines, though alternating magnetic fields of high densities are hardly practicable. The number of polar laminations does not seem to be important. The experiments were made with currents of 85 periods per second. At higher frequencies, 150 and 350, the particles stand up in filaments like brushes, but the translation movements become weak in feebly magnetic substances.

Mr. Cecil C. Mason, of the Cambridge and Paul Scientific Instrument Company, exhibited a novelty about which little information was available, an autographic record of the loss of rotational velocity of a projectile during flight. A curve of spin against time was obtained on a disc, clock-driven inside the shell; it formed a curved band ending at the moment when the shell had struck the water; the disc was mounted for micrometer measurement. This was a private exhibit of Mr. Mason's, shown by permission of the Ordnance Committee. The exhibits of the Cambridge Company comprised a portable CO_2 recorder of the katharometer type, expressly designed for measuring the carbon dioxide in the alveolar air. Their other exhibit was the micro-indicator of Mr. W. G. Collins for taking diagrams of high-speed engines, especially suitable for track tests and aeroplane engines in flight. Within less than a minute ten indicator diagrams are permanently traced on a celluloid disc by a very compact apparatus. We have, however, to hold over a description of this and other noteworthy novelties till next week, and at present we can only mention in conclusion that the one discourse of the evening, given by Lord Rayleigh, was on the Aurora Borealis and its Spectrum, with particular regard to recent observations in the south of England.

(*To be continued.*)

NOTES ON NEW BOOKS.

There was annually produced by the world before the war almost 1,000,000 tons of zinc, and yet for such a considerable business as this implies the technical literature is not in keeping, as it is limited in extent and poor in quality. Whether this is the result of the primitive methods employed and the lack of appreciation of those in charge, or the cause of them, it is impossible to say, but it certainly makes one turn with interest to every new book on the subject which is published, hoping that it will give evidence of the progressive spirit which seems so absent. "*The Metallurgy of Zinc and Cadmium*" (New York and London: McGraw-Hill Book Company; price 20*s.* net), by Professor Hofman, of the Massachusetts Institute of Technology, has just been published, and we have searched it in vain for any evidence of new work being done on the difficult problems of zinc manufacture. This treatise is mainly descriptive of plant and methods in actual use in zinc producing districts, together with descriptions of the more important properties of zinc compounds and ores. It is copiously illustrated with diagrams and drawings, the bulk of which are dimensioned, and it is a work which should be well suited for plant engineers. It is especially good where the work of American companies is concerned as it has obviously been compiled from first hand observation. Few processes or even proposed processes seem to have escaped the eye of the author, but it is questionable whether in many cases it was worth while noticing some of those which will never get beyond the paper stage. This is probably the best book on the subject yet published, but we believe that a treatise on the scientific metallurgy of zinc is still badly wanted.

Although the well-being and even the life of a community depend so largely upon the organisation of its sanitary services, there is probably no branch of municipal engineering of which the ordinary citizen is more ignorant than the sewerage of his district. Most of the system is underground and invisible, and such works as are on the surface are always located in some district where the general public do not commonly resort. As our sewers are constructed and operated under the control of popularly elected bodies, it is well that an elementary knowledge of the principles and practice of sewerage should be available to the public, and in "*Sewers and Sewerage*," by H. Gilbert Whyatt, M.Inst.C.E. (London: Sir Isaac Pitman and Sons, Limited, price 2*s.* 6*d.* net), the author outlines the subject in a popular manner. The law relating to sewers is briefly related. The computations necessary in connection with the installation of a system are exemplified, and details of construction and methods of cleaning, &c., are all illustrated. The book will give the lay reader a very clear and accurate idea of what a sewer system is, and the student will find much in the way of tables and data which will interest him. Like all of Messrs. Pitman's "*Technical Primer Series*," the present little book is well printed and illustrated, and though elementary, it is authoritative.

When one comes to consider how much of the cost of any article of commerce is directly attributable to the transportation of raw material or of finished or semi-finished components, the question of transportation in relation to prices is seen to have a greater importance than is generally recognised. The carriage of goods over vast distances by sea and land is only one aspect of the question, for rail and ocean transport have been so carefully studied that, on the whole, they are very efficiently performed. It is the smaller movements which run away with the money; the loading and unloading of cars, the carriage of material from shop to shop and from machine to machine, and the countless changes of position which are involved during the processes of manufacture. In "*The Mechanical Handling of Goods*," Mr. C. H. Woodfield, M.I.Mech.E., has written a readable little treatise, summarising in a general way the methods and equipment adopted in modern factories. It is well illustrated and gives a good idea of appliances such as cranes, runways, conveyors, elevators, trucks, &c., which are used to facilitate and cheapen the handling of materials. The elevating and conveying of material by means of air is another form of transportation which has many applications. The system is dealt with in "*Pneumatic Conveying*," by Mr. E. G. Phillips, M.I.E.E., who gives a concise account of the methods adopted. Pneumatic conveying is generally associated with the handling of grain, but ashes, coal, oranges, sugar, iron ore, spent tanning bark, &c., are now transported, elevated or conveyed pneumatically. Both the above books are published at the price of 2*s.* 6*d.* net each by Sir Isaac Pitman and Sons, London.

THE NEWCOMEN SOCIETY.—This society, which has as its object the study of the history of engineering and technology, will hold its summer meeting in London on June 1 and 2 next. On the morning of the first day a visit will be paid to the engineering collections at the Science Museum, South Kensington, whilst in the afternoon the famous roof of Westminster Hall will be inspected, after which the party will visit the Clockmakers' Company's horological collection in the city. On the following day the Rotunda Museum at Woolwich will be visited, and the Boulton and Watt engines at the Brooknull-road Station of the Metropolitan Water Board.

THE ROYAL INSTITUTION OF BRITISH ARCHITECTS.—A series of five public lectures on architecture will be given at the Galleries of the Royal Institute of British Architects, 9, Conduit-street, W. 1, on the following dates, at 5 p.m.: May 18, Mr. Halsey Ricardo (F.), "The Value of Public Opinion"; May 25, Professor Ernest A. Gardner (Yates Professor of Archæology, University College, London); "Greek Public Buildings"; June 8, Mr. D. S. Maccoll, M.A., LL.D. (Keeper of the Wallace Collection), "What is Architectural Design?"; June 15, Professor C. H. Reilly, M.A. (Roscoe Professor of Architecture, University of Liverpool), "Some London Streets and their Recent Buildings"; June 21, Mr. W. H. Bidlake, M.A.(Cantab.), "The Continuity of English Architecture."

X-RAY STUDIES ON THE CRYSTAL STRUCTURE OF STEEL.*

By Dr. ARNE WESTGREN and GÖSTA PHRAGMÉN (Stockholm, Sweden).

AT the annual meeting last year one of the present authors presented a report on some X-ray crystallographic investigations on iron and steel.† The photograms on which his conclusions regarding the crystal structure of the steel components were based were, however, unfortunately not as clear as could have been desired, and a reproduction of them was therefore not given. Because of the spontaneous grain growth at higher temperatures the photogram of γ-iron (1,000 deg. C.) did not show any continuous lines, but only a few remote spots.

The authors have now carried on those investigations with improved experimental arrangements and have obtained photograms clear enough for reproduction. A reconstruction of the camera for exposures at high temperature, mentioned in the preceding paper, has enabled them to let the glowing iron wire rotate during the X-ray illumination. They have thus obtained not only a very distinct line photogram of γ-iron (1,100 deg. C.) but also succeeded in determining the structure of δ-iron (1,425 deg. C.). Through using more exact methods they have been able to ascertain the deforming influence of dissolved carbon on the γ-iron lattice in austenite. A combination of the Debye-Scherrer method

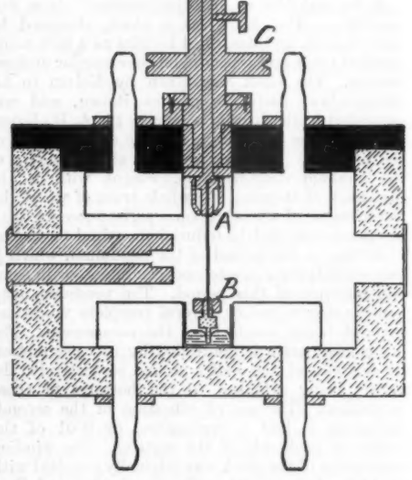


FIG. 3. SHOWING CONSTRUCTION OF CAMERA.

with the X-ray analytic procedure of Laue and the investigation of the X-ray reflections of a rotating crystal have finally made it possible to determine the crystal shape and the elementary volume of cementite.

Experimental Arrangements.—The X-rays were produced in a tube of the Siegbahn type.‡ As stated, it has sometimes been difficult to get the metal body of those tubes, when made of bronze, quite vacuum tight. Another material was therefore tried, extremely free from all kinds of slag inclusions and heterogeneities, and therefore, as might be expected, quite satisfactory, namely, S.K.F. ball-bearing steel. It completely responded to expectations.

The anti-cathode was cut off perpendicularly to its axis, and in order to get the characteristic X-rays of iron, very convenient for these investigations, an iron plate was soldered on to it. Round the radiating anti-cathode surface five windows were made. Thus the tube gave five beams and exposures could be made in five cameras simultaneously.

The tube was evacuated through an aggregate of a mercury vapour jet pump and a mercury diffusion pump of the Volmer type. In front of the jet pump a glass bottle of about 10 litres content was introduced and was exhausted together with the pumps and the tube, to a pressure of about 3 mm. of mercury. If the system proved tight this primitive vacuum could be kept up for any length of time. It was found that no special arrangement for cooling the mercury vapour was necessary in order to obtain the desired vacuum. When the pumps had been at full work a few minutes the pressure in the tube had decreased so much, that at the voltage used (maximum of effective voltage, 50,000 volts) no current could pass. A special arrangement had therefore to be devised to supply the tube continuously with a

* Paper read before the Iron and Steel Institute, May 5, 1922.

† Journal of the Iron and Steel Institute, 1921, No. 1, page 303.

‡ *Zeitschrift für Physik*, 1920, vol. iii, page 369; *Zeitschrift für Physikalische Chemie*, 1921, vol. xcviii, page 181.

proper amount of air in order to keep it at a constant suitable pressure. For that reason a capillary glass tube of about 0·5 m. length and 0·2 mm. width was connected with the tube on the side opposite to the exhaust opening. This tube was connected with a glass bottle containing air, the pressure of which could easily be regulated by connecting it with an air vessel of somewhat higher or of somewhat lower air pressure. Through this arrangement the pressure in the X-ray tube could very easily be kept constant at any state, and the tube could thus be run at any voltage desired. It was usually charged with 45,000 volts to 50,000 volts and run with 10 milliamperes to 12 milliamperes.

Fig. 1, Plate XXV, is a photograph of the apparatus. As may be seen, the pumps are placed below the tube. The low-vacuum vessel and the regulation arrangement are arranged on the far side of the wood support, and are visible on the photograph of the back of the apparatus, reproduced in Fig. 2, Plate XXV.

This photograph also gives a general view of the arrangement for taking photograms of iron at higher temperature. The construction of the camera is made clear in Fig. 3. In regard to its main feature reference may be made to the description given in the paper read before this Institute last year. Only the lip and the central part have been changed. The lid is made of ebony and the brass parts in the centre are thus electrically insulated from the lead body of the camera. A and B are brass chucks between which the iron wire is stretched vertically. The latter, the lower part of which is made of iron, dips into mercury, which is poured into a little iron cylinder in the centre of the lower cooling vessel. A is fixed to a rotary brass axle, which has on its upper end a little driving wheel C, to be slowly turned (three to four rotations per minute) with the aid of the electromotor seen on the left in Fig. 2. The film was covered with an envelope of black paper. To prevent any light from the glowing wire leaking in at the edges of the hole in its centre, the hole was bordered with thin cardboard rings, and the paper between the rings pressed to the film with the aid of an annular brass screw. The iron wire in the camera was heated by an alternating current of low voltage. The temperature was determined with the aid of an optical pyrometer (Holborn-Kurlbaum).

Crystal Structure of the Iron Modifications.—To determine the crystal structure of pure iron at different temperatures a 0·3-mm. wire of vacuum-melted electrolytic iron (delivered by W. C. Heraeus, Hanau a/M.) containing 99·98 per cent. of the metal, was investigated. Photograms were taken at ordinary temperature and at about 800 deg., 1,100 deg. and 1,425 deg. C. The time of exposure was 2½ hours. The films are shown in Fig. 4, I to VI, Plate XXV. As may be seen, the photograms of α and β iron are of the same type. The only difference is that the lines of the latter, because of the heat expansion, are removed somewhat nearer to the centre of the photogram. The γ-iron photogram is of quite another type.

TABLE I.—*Correction for the High-Temperature Camera.*

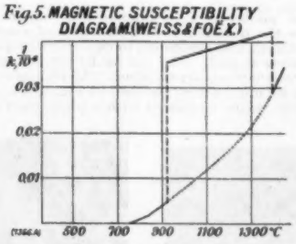
r.		Correction Term.	I.
Obs.	Calc.		
25·6	24·6	− 1·0	w.
28·4	27·3	− 1·1	st.
37·3	36·2	− 1·1	w.
41·9	40·6	− 1·3	st.
47·6	46·5	− 1·1	w.
55·0	53·3	− 1·7	st.
59·1	57·4	− 1·7	w.
71·6	69·3	− 1·3	st.
73·6	72·1	− 1·5	w.

TABLE II.—*β-Iron.* 800 *Deg. C.*

r.		I.	$\sin^2\frac{\theta}{2}$	$k(h_1^2+h_2^2+h_3^2)$.	$h_1h_2h_3$.	Radiation.
Meas.	Corr.					
25·0	24·0	w.	0·179	2·0,0895	110	K_β
28·0	26·9	st.	0·221	2·0,1105	110	K_α
37·0	35·9	w.	0·368	4·0,0920	200	K_β
41·6	40·3	st.	0·446	4·0,1115	200	K_α
47·7	46·6	w.	0·563	6·0,0938	211	K_β
54·3	52·6	st.	0·669	6·0,1115	211	K_α
69·5	68·2	st.	0·895	8·0,1119	220	K_α
72·3	70·8	w.	0·922	10·0,0922	310	K_β

$a_\beta = 2{\cdot}90$ Å.U.

In the photograms taken at the highest temperature the lines are broad and not very distinct. This is due to the fact that the iron wire at this temperature is extremely pliable. An irregular bending of the wire through the torsion and the capillary forces of the mercury could therefore not be avoided, and the position of the wire changed somewhat during the exposure. It proved very difficult to keep the temperature of the wire steadily within the δ-iron interval. If it were kept so high that the pyrimeter showed 1,450 deg. C., the wire became so soft that it could not stand the torsion and generally melted off after a few minutes. The temperature had therefore to be kept at about 1,425 deg. C., that is, well in the vicinity of the γ-δ transformation point. Preliminary tests had proved that it was necessary to counteract the influence of the grain growth in the heated iron. For that purpose its temperature was changed every fifth or tenth minute into the range of another crystal structure. In taking the β-iron photogram the temperature was every now and then raised for a moment to about 1,000 deg. C., and when the γ and δ-iron were investigated the heating current was now and then broken off for a moment to let the wire cool down into the α-range. The crystal aggregate was thus changed at intervals. When this procedure was carried out with the δ-iron it proved difficult to obtain the desired temperature equilibrium by reheating the wire. Thus it could not be avoided that sometimes during the exposure the wire was not heated to a sufficiently high temperature, and consequently the photograms IV and V (Fig. 4) contain the γ-iron lines. Other lines also appear, however, In IV the γ-iron photogram is distinct and the other lines weak, but in V the intensity of the line series is reversed. Both films evidently contain a mixture of the γ and δ-iron photograms. In getting film V special care was taken to keep the temperature as far as possible above the transformation point, and therefore the δ-lines in that photogram dominate. Though the temperature in this last case had generally been a little higher than when film IV was taken, the inmost lines are more distant from each other in V than in IV. In V those lines therefore must



also belong to the δ-iron. From a comparison of V and VI, that is the α-iron photogram, it is obvious that the δ-iron has the same structure as α-iron.*

TABLE III.—*γ-Iron.* 1,100 *Deg. C.*

r.		I.	$\sin^2\frac{\theta}{2}$	$k(h_1^2+h_2^2+h_3^2)$.	$h_1h_2h_3$.	Radiation.
Meas.	Corr.					
24·8	23·8	w.	0·176	3·0,0587	111	K_β
27·5	26·4	st.	0·213	3·0,0710	111	K_α
28·5	27·7	v.w.	0·232	4·0,0580	200	K_β
32·2	31·1	st.	0·287	4·0,0717	200	K_α
42·5	41·3	v.w.	0·465	8·0,0581	220	K_β
48·0	46·8	st.	0·566	8·0,0708	220	K_α
52·5	51·0	v.w.	0·640	11·0,0582	311	K_β
60·7	59·0	st.	0·771	11·0,0701	311	K_α
65·6	64·3	st.	0·846	12·0,0705	222	K_α

$a_\gamma = 3{\cdot}63$ Å.U.

TABLE IV.—*γ (+ δ) Iron.* 1,425 *Deg. C.*

r.		I.	$\sin^2\frac{\theta}{2}$	$k(h_1^2+h_2^2+h_3^2)$.	$h_1h_2h_3$.	Radiation.	Iron, modification.
Meas.	Corr.						
24·5	23·5	w.	0·172	3·0,0573	111	K_β	γ
27·0	25·9	st.	0·206	3·0,0687	111	K_α	γ
31·4	30·3	m.	0·274	4·0,0685	200	K_α	γ
47·6	46·4	st.	0·558	8·0,0697	220	K_α	γ
53·1	51·6	st.	0·650	6·0,1083	211	K_α	δ
59·6	58·1	st.	0·757	11·0,0688	311	K_α	γ
64·4	62·9	st.	0·828	12·0,0690	222	K_α	γ
67·9	66·4	st.	0·874	8·0,1093	220	K_α	δ

$a_\gamma = 3{\cdot}68$ Å.U. $a_\delta = 2{\cdot}93$ Å.U.

TABLE V.—*δ (+ γ) Iron.* 1,425 *Deg. C.*

r.		I.	$\sin^2\frac{\theta}{2}$	$k(h_1^2+h_2^2+h_3^2)$.	$h_1h_2h_3$.	Radiation.	Iron, modification.
Meas.	Corr.						
25·0	24·0	w.	0·179	2·0,0895	110	K_β	δ
27·5	26·5	st.	0·216	2·0,1080	110	K_α	δ
31·4	30·3	w.	0·274	4·0,0685	200	K_α	γ
41·1	40·0	m.	0·442	4·0,1105	200	K_α	δ
47·2	46·1	w.	0·552	8·0,0690	220	K_α	γ
53·0	51·5	st.	0·650	6·0,1083	211	K_α	δ
59·3	57·8	m.	0·753	11·0,0685	311	K_α	γ
64·0	62·5	w.	0·823	12·0,0686	222	K_α	γ
67·8	66·3	st.	0·872	8·0,1090	220	K_α	δ

$a_\gamma = 3{\cdot}68$ Å.U. $a_\delta = 2{\cdot}93$ Å.U.

Because of the envelope with its cardboard lining at the hole, the films have not been orientated exactly cylindrically around the iron wire. The X-ray beam was faintly divergent and the films have shrunk a little in the photographic treatment. To eliminate the errors from these circumstances the α-iron photogram was compared with a theoretically calculated ideal photogram. The displacement of the lines on the films taken in the camera for high temperature exposures, which were all orientated in exactly the same way, could thus be eliminated. In Tables I to V r indicates the distance, measured in millimetres, from the centre of the photograms to the middle of the lines. Table I contains the r values of the α-iron photogram together with the calculated corresponding values of the ideal photogram. The resulting correction terms are given in the third column, and I, the intensity of the lines, in the fourth (v.w. = very weak, w. = weak, m. = medium intensity, st. = strong).

Tables II to V contain the results of the investigations of β, γ and δ-iron. θ is half the apex angle of the cones of the interference radiation, k a constant, and h_1, h_2, h_3 the crystallographic indices of a surface in the lattice. In the last column of the tables the X-ray radiation is stated.

The results given in Tables II and III fully confirm the statement that the iron at 800 deg. C. has a body-centred and the γ-iron a face-centred cubic lattice. The sides of the elementary cubes, calculated according to the formula:

$$a^2 = \frac{\lambda^2(h_1^2+h_2^2+h_3^2)}{4\sin^2\frac{\theta}{2}}$$

where λ is the wave-length of the iron radiation—$K_\alpha = 1{\cdot}932$ Å.U. and $K_\beta = 1{\cdot}754$ Å.U.—are given below the tables.

For α-iron at ordinary temperature a has been found to be 2·87 Å.U., at 800 deg. C. it has increased to 2·90 Å.U., and at 1,425 deg. C. it has grown to 2·93 Å.U. This agrees very well with the known dilatation coefficient of α-iron, the mean value of which from 20 deg. to 800 deg. C. is $15{\cdot}10^{-6}$. The heat expansion of the γ-iron also manifests itself in the increase of a_γ from 3·63 Å.U. at 1,100 deg. C. to 3·68 Å.U. at 1,425 deg. C., which agrees well with the fact, that the dilatation coefficient of γ-iron is greater than that of α-iron.

From the investigations of the space lattice of heated iron described it follows that iron, although it has been considered to have four allotropic modifications only, appears in two different crystal forms. α, β and δ-iron have a body-centred cubic and γ-iron a face-centred cubic lattice.

It may at first view appear rather startling that the transformation that takes place at A3 is reversed at the higher temperature A4. The diagram of Weiss and Foëx,* reproduced in Fig. 5, which shows the change of the magnetic susceptibility of iron with the temperature, had shown, however, that an identical structure of α, β and δ-irons was very probable. The curve within the δ range may very well be regarded as a continuation of the lower temperature part of it. The γ-iron part can thus be considered to be removed out of the continuous curve (in the figure partly indicated with a dotted line).

The Influence of Carbon on the Space Lattice of Iron in Hardened Steels.—In the above-mentioned paper by A. Westgren, presented last year, it was stated that in two different austenitic steels the space lattice of γ-iron was not exactly of the same size. During the discussion it was pointed out by Sir William Bragg† that this probably was due to the difference in carbon content. One steel contained 25 per cent. nickel and 0·24 per cent. carbon, the other one 12 per cent. of manganese and 1·34 per cent. carbon.

The possibility must, however, also be taken into consideration, that the real cause of the variation in the lattice dimensions might depend on the different qualities of the alloyed special metals. To settle this question a more exact photogram was taken on the above-mentioned nickel steel, and an investigation was also made on a steel with almost the same nickel content but holding much more carbon. The latter, which Sir Robert Hadfield kindly put at the author's disposal, contained 24·3 per cent. nickel, 6·1 per cent. manganese, and 1·18 per cent. carbon. In comparison with the amount of nickel the content of manganese is low and can hardly be considered to have any influence on the lattice.

The steels were quenched in water from 1,000 deg. C. and were investigated in the shape of rods, ground to a diameter of 0·5 mm. In order to get the X-ray beam illuminating the sample as exactly defined as possible without wasting time with a long exposure, the tube of the camera used was made 40 mm. long and had a diameter of only 1 mm. The diameter of the film in this camera was 55 mm. The films taken in this camera and in two other cameras with film cylinders of 50 mm. and 60 mm. diameter, mentioned in the following, were corrected in the same manner as was described for the high temperature camera. r-values below 50 mm. must be reduced with 0·6 mm., and with increasing r the correction grows to 1 mm. for the smaller camera and to 1·3 mm. for the biggest one. The time of exposure was generally 3 hours.

The results of the measurement of two nickel steel films are given in Tables VI and VII. As may be seen, the k-values of the two tables differ very much, which proves that the space lattices of these steels are of a different size. The side of the elementary cube is found to be 3·64 Å.U. for the steel with the higher carbon content, which is greater than the corresponding distance in the pure γ-iron lattice at 1,100 deg. C. In the other steel the side of the elementary cube is only 3·56 Å.U. The films are given in Fig. 6, I and II, Plate XXV.

* A. W. Hull, *Phys. Rev.*, vol. xvii, page 571 (1921), has recently found that atoms in cobalt are either grouped in a face-centred cubic lattice or in a close packed hexagonal one, both of which are in a very simple way related to each other. As the γ-iron evidently corresponds with the former of these cobalt modifications, it might be expected that the δ-iron should have hexagonal structure of the cobalt type. The position of the δ-lines is, however, not in accordance with such a supposition, which therefore must be renounced as untenable.

* *Journal Phys.*, 1911, vol. i, page 745; *Archives des Sciences Phys. et Nat.* (iv), 1911, vol. xxxi, page 18.

† Journal of the Iron and Steel Institute, 1921, No. I, page 327.

In order to ascertain the influence of the hardening temperature on the iron lattice in the austenite, photograms were also taken on a plain carbon steel with 1·98 per cent. carbon. From this steel two samples were made, both quenched in water, the one at 1,000 deg. C. and the other one at 1,100 deg. C. The values of

$$\frac{\sin^2\frac{\theta}{2}}{h_1^2+h_2^2+h_3^2}$$

obtained from the photograms taken in the smaller and more exact cameras are given in Table VIII, and one of the films is reproduced in Fig. 6, IV, Plate XXV, where it can be compared with the photograms of pure α and γ-iron. These steels contain a mixture of austenite and martensite, and in the photograms γ-iron lines as well as α-iron lines appear. The former are very distinct but the latter are faint, broad and diffuse, indicating that the α-iron crystals in the martensite are extremely minute.

The a values are given below the column of Table VIII from which they are calculated. As may be seen, the meshes of the γ-iron lattice in these steels are also a little widened by the dissolved carbon. The elementary cube is bigger than that of pure γ-iron at 1,100 deg. C. A slight difference can even be noted between the steel hardened at 1,100 deg. and that hardened at 1,000 deg. The austenite of the former, in which evidently more carbon is dissolved, has a somewhat larger space lattice.

A further interesting point concerning this effect should be noted. The carbon atoms may be situated in the cavities of the iron lattice,* but they are certainly distributed quite irregularly in the austenite crystals. If their deforming influence were of a local nature, that is, limited to the atoms in their immediate neighbourhood, the interference radiation would be diffuse. The lines of the photograms of the austenite containing considerable carbon are, however, very distinct and clear, which proves that the iron lattice is uniformly deformed by the carbon.

The martensite content in the above-mentioned steels manifests itself only in three very faint and diffuse lines in the photograms. Their cloudiness makes it difficult exactly to determine the position of their intensity maxima. The a-values of the α-iron in the martensite obtained from the data of Table VIII must therefore be considered to be rather unreliable. All four photograms have, however, given the same value, viz., 2·90 Å.U., which indicates that the α-iron lattice of the martensite is likewise enlarged by the carbon atoms present.

As this matter is of a fundamental importance in regard to the question of the structure of martensite, the investigation was extended to two ordinary quenched carbon steels as well. The one held 1·24 per cent. and the other one 0·80 per cent. carbon. The photograms (film diameter, 60 mm.) are reproduced in Fig. 7, Plate XXV, where they can be compared with a photogram of pure

the table is not very good, which must be ascribed to the difficulty of exact determination of the r-values. It seems, however, as if the iron atoms in the martensite have been a little removed from each other by the carbon present—the a-values found are generally higher than 2·87 Å.U.—and if the results may be relied upon, they indicate that the carbon, as mostly supposed, is so intimately mixed with the iron that it may be considered to be in a real atom disperse solution.

There has been much discussion on the question of whether the carbon in martensite is present as carbon atoms, as Fe_3C molecules, or even as colloidally dissolved Fe_3C. One of the present authors has, in a correspondence* on the slip interference theory of Zay Jeffries and R. S. Archer,† opposed the first of these assumptions. Jeffries‡ has recently more thoroughly developed his arguments against the supposition that Fe_3C molecules are present in martensite. The authors wish to avail themselves of the opportunity to admit that they believe Jeffries' conclusion to be correct.

It is not advisable without consideration to use terms borrowed from chemistry (which hitherto has dealt mainly with liquid solutions and gases) to describe solid systems. The main point is whether martensite is a system of two phases or a homogeneous solid atom disperse solution. In the latter case it should be asked, what influence have the carbon atoms on the iron lattice? Is it locally distorted? In that case it might be possible that the carbon atoms may be able, according to their

FIG. 9. SPECIMEN OF SPIEGEL, PROBABLY SOLIDIFIED UNDER BLAST-FURNACE SLAG. (ROYAL TECHNICAL HIGH SCHOOL, STOCKHOLM.)

FIG. 10. PORTION OF SPIEGEL, SHOWN IN FIG. 9, ON ENLARGED SCALE.

TABLE VI.—*Nickel Steel (Nickel, 24·3 per Cent.; Manganese, 6·05 per Cent.; Carbon, 1·18 per Cent.) Quenched from 1,000 Deg. C. in Water. Diameter of Film Cylinder, 55 MM. Time of Exposure, 3 Hours.*

r. Obs.	r. Corr.	I.	$\sin^2\frac{\theta}{2}$.	$k(h_1^2+h_2^2+h_3^2)$.	$h_1h_2h_3$.	Radiation.
24·1	23·5	w.	0·171	3·0,0570	111	K_β
26·8	26·2	st.	0·211	3·0,0703	111	K_α
28·1	27·5	w.	0·230	4·0,0575	200	K_β
31·4	30·8	st.	0·282	4·0,0705	200	K_α
42·0	41·4	w.	0·466	8·0,0582	220	K_β
47·1	46·4	st.	0·558	8·0,0698	220	K_α
51·5	50·8	w.	0·637	11·0,0579	311	K_β
60·5	59·6	st.	0·780	11·0,0709	311	K_α
65·9	64·9	st.	0·856	12·0,0713	222	K_α

$a_\gamma = 3·64$ Å.U.

TABLE VII.—*Nickel Steel (Nickel, 25·2 per Cent.; Carbon, 0·24 per Cent.). Quenched from 1,000 Deg. C. in Water. Diameter of Film Cylinder, 55 MM. Time of Exposure, 3 Hours.*

r. Obs.	r. Corr.	I.	$\sin^2\frac{\theta}{2}$.	$k(h_1^2+h_2^2+h_3^2)$.	$h_1h_2h_3$.	Radiation.
24·7	24·1	w.	0·180	3·0,0600	111	K_β
27·6	27·0	st.	0·223	3·0,0743	111	K_α
28·8	28·2	v.w.	0·240	4·0,0600	200	K_β
32·2	31·6	st.	0·295	4·0,0738	200	K_α
43·0	42·6	v.w.	0·488	8·0,0610	220	K_β
48·8	48·1	st.	0·587	8·0,0734	220	K_α
53·0	52·8	v.w.	0·671	11·0,0610	311	K_β
63·0	62·1	st.	0·817	11·0,0743	311	K_α
67·5	66·5	st.	0·887	12·0,0739	222	K_α

$a_\gamma = 3·56$ Å.U.

The investigations have thus conclusively shown that carbon dissolved in γ-iron has a distorting influence on its lattice.

TABLE VIII.—*Steel with 1·98 per Cent. Carbon.*

$\frac{\sin^2\frac{\theta}{2}}{h_1^2+h_2^2+h_3^2}$ Film Diameter, 50 MM. Qu'nch'd at 1,000 Deg. C.	Film Diameter, 50 MM. Qu'nch'd at 1,100 Deg. C.	Film Diameter, 55 MM. Qu'nch'd at 1,000 Deg. C.	Film Diameter, 55 MM. Qu'nch'd at 1,100 Deg. C.	I.	$h_1h_2h_3$.	Radiation.	Iron Modification.
0·0573	0·0567	0·0580	0·0570	w.	111	K_β	γ
0·0905	0·0905	0·0910	0·0915	w.	110	K_β	α
0·0697	0·0683	0·0703	0·0697	st.	111	K_α	γ
0·1095	0·1105	0·1095	0·1105	st.	110	K_α	α
0·0698	0·0688	0·0703	0·0697	m.	200	K_α	γ
0·0575	0·0573	0·0575	0·0577	w.	220	K_β	γ
0·0707	0·0701	0·0708	0·0701	st.	220	K_α	γ
0·0577	0·0579	0·0586	0·0585	v.w.	311	K_β	γ
0·1118	0·1115	0·1112	0·1112	w.	211	K_α	
0·0582	0·0579	0·0584	0·0582	v.w.	222	K_β	γ
0·0707	0·0704	0·0707	0·0704	st.	311	K_α	γ
0·0708	0·0705	0·0707	0·0702	st.	222	K_α	γ
$a_\alpha = 2·90$ Å.U.	2·90 Å.U.	2·90 Å.U.	2·90 Å.U.				
$a_\gamma = 3·64$ Å.U.	3·66 Å.U.	3·64 Å.U.	3·65 Å.U.				

α-iron. A very interesting difference between them may be noted. They have both very cloudy and diffuse lines, but this effect is much more pronounced in the film of the steel 0·80 than in the other one. The outermost lines of the former are widened to about 5 mm. broad shadows. The values of

$$\frac{\sin^2\frac{\theta}{2}}{h_1^2+h_2^2+h_3^2},$$

corresponding to the lines in the photograms of these steels, are given in Table IX. The concordance within

* Compare with Sir W. H. Bragg, *loc. cit.*, page 327.

TABLE IX.—*Carbon Steels Quenched at 760 Deg. C.*

$\frac{\sin^2\frac{\theta}{2}}{h_1^2+h_2^2+h_3^2}$ Film Diameter, 60 MM. C, 0·80.	Film Diameter, 60 MM. C, 1·25.	Film Diameter 55 MM. C, 0·80.	I.	$h_1h_2h_3$.	Radiation.
0·0925	0·0915	0·0880	0·0920	0·0895	w.	110	K_β
0·1140	0·1115	0·1080	0·1120	0·1095	st.	110	K_α
0·1142	0·1115	0·1115	0·1125	0·1125	m.	200	K_β
—	0·0922	—	—	—	w.	211	K_β
0·1137	0·1132	0·1107	0·1132	0·1129	st.	211	K_α
—	0·1133	—	0·1130	—	st.	220	K_α
$a = 2·87$ Å.U.	2·88 Å.U.	2·91 Å.U.	2·88 Å.U.	2·89 Å.U.			

concentration, to form a grouping of iron and carbon atoms more or less in accordance with the cementite structure. It is possible that in this way transition forms between the pure α-iron lattice and the cementite grouping of atoms can arise. The conception of individual molecules of a sharply-defined type is not rational in this connection.

If the iron lattice be uniformly deformed, it seems probable that martensite, like austenite, is a true solid solution of carbon in iron. If the photogram of martensite be identical with that of pure α-iron it indicates that the hardened steel contains a mass of α-iron particles free from carbon. In that case the martensite probably would be a colloid.

The photograms so far obtained seem to point in the direction of the first of these possibilities. It is thus probable that martensite is a real atom disperse solution. For reasons mentioned, the values of r found cannot,

* *Chemical and Metallurgical Engineering.*—1921, vol. xxv., page 641.

† *Chemical and Metallurgical Engineering*, 1921, vol. xxiv, page 1057.

‡ *Ibid.*, 1922, vol. xxvi, page 250.

however, be considered as perfectly reliable, and therefore this question must be regarded as not yet definitely settled.

The diffuseness of the lines in the photograms gives, however, very important information as to the structure of martensite. As P. Scherrer* has shown the lines of a Debye-Scherrer photogram get broader and more diffuse in proportion as the crystal powder is more finely divided. Scherrer has even worked out a method to determine the average size of the grains in the powder, based on measurements of the line breadth. For want of instruments for exact photometric investigations of the photograms no quantitative determination in this direction could be performed. From a qualitative comparison of the film of steel 0·80 with a photogram of an extremely fine-grained gold colloid reproduced in the communication of Scherrer, it might, however, be concluded that the steel is as highly disperse as the colloid. The lines of the martensite seem to be of about the same breadth as the lines in the gold photogram. The ranges of homogeneous lattice in the steel have accordingly on an average an extension of about 20 Å.U., and each of them contains only a few hundred atoms. Martensite can thus be considered to be on the verge of being totally amorphous. This is an important fact that must be taken into consideration in all future speculations on the causes of the hardness of martensite.

The Crystal Shape of Cementite.—The statements as to the crystal shape of cementite hitherto occurring in literature must be considered to be very vague. In a survey on this matter, P. Groth† mentions that Fe_3C and isomorphous mixtures with Mn_3C forming part of ferro-manganese or "spiegel" iron crystallise in orthorhombic prisms or tablets, which have been investigated by Rammelsberg,‡ Hlawatsch,§ Mallard,‖ and especially by L. J. Spencer.¶ Isomorphous mixtures of Fe_2Si and Mn_2Si with the corresponding carbides have been found to be triclinic pseudohexagonal** or orthorhombic bipyramidal.†† As Groth has pointed out, it is, however, not justifiable without further investigation to consider the cementite occurring in steel as isomorphous with any of these products.

On account of the difficulty of obtaining crystals of pure cementite sufficiently large for goniometric measurements, it has hitherto been impossible to perform any investigations of this kind. The crystal form of cementite would therefore certainly still have been unknown if the method of Debye and Scherrer had not rendered it possible to determine the crystal structure of fine-grained material.

In order to produce a cementite powder suitable for such an investigation a hypereutectoid steel (carbon, 1·25 per cent.) and a white cast-iron, used for tempering purposes, were electrolytically dissolved in normal acetic acid. One of the steel samples had been kept at a temperature of 900 deg. C. during 5 hours, and then slowly cooled, by means of which treatment the cementite had gathered at the grain boundaries and was collected into larger crystals. After having been corroded by acid for 24 hours the samples were covered with a coat of cementite, which was carefully scraped off. The cementite powder was then washed with diluted acetic acid alcohol and ether, and dried at 100 deg. C. The annealed steel in this way gave a crystal powder with very nearly the composition calculated from the formula Fe_3C (carbon, 6·67 per cent. iron; iron, 93·33 per cent.). The cementite obtained from the pearlitic steel and the cast-iron proved to have a little too high a carbon content, which must be ascribed to the partial decomposition caused by the acid. The analyses are given in Table X.

TABLE X.—*Composition of the Cementite Preparations.*

——	Fe.	C.	Mn.
Cementite of annealed steel (grain boundaries)	92·3	6·85	0·76
Cementite of unannealed steel (lamellar pearlite)	—	8·90	—
Cementite of cast iron	—	11·65	—

The three different powders gave identical Debye photograms. From this fact it may be concluded that the cementite in all three alloys is probably composed of a unit chemical individual. The most distinct photogram is reproduced in Fig. 8, II, Plate XXV.

As may be seen, it contains a very great number of lines from which it can at once be deduced that cementite is of complicated structure. A more thorough investigation of the photogram soon showed that any attempt to find its quadratic formula would certainly fail. The problem had therefore to be attacked in another way. Endeavours were made to find a ferrous alloy, developed into larger crystals, with the same structure as cementite. As already mentioned, crystals of analogous composition have been observed, and it might therefore be expected that such a method should be successful.

Among investigated products of this kind there was one that gave a Debye photogram identical with that of cementite. It is given in Fig. 8, I, Plate XXV. It was obtained from a piece of spiegel, probably solidified under some slag in a blast-furnace put out of blast. On its upper side a vast number of thin tablets had grown, which, according to the X-ray investigations must be regarded as developed cementite crystals. A chemical analysis gave the result: 13·1 per cent. manganese; 5·1 per cent. carbon, and 0·05 per cent. silicon. The value of the carbon content is lower than the theoretical value corresponding with the formula Fe_3C. This is caused by the fact that the crystals, as was later found, are decarburised on their surface. A photograph of this very decorative iron piece, that belongs to the Royal Technical High School in Stockholm, is given in Fig. 9, page 632. Fig. 10 shows a portion of it in a larger scale.

A Debye photogram of the compact part showed in addition to the cementite lines faint γ-iron lines. From one of these crystals was taken a Laue photograph, the direction of the X-ray beam being perpendicular to the natural surfaces of the crystal plate. The photogram is reproduced in Fig. 11, below, and the corresponding gnomonic projection in Fig. 12.* Cleavage planes of the

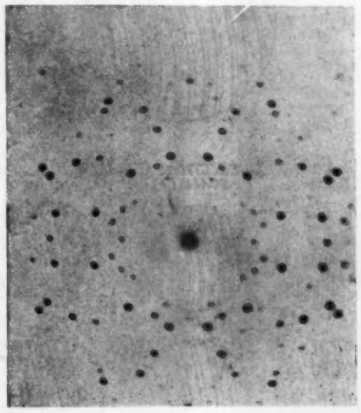
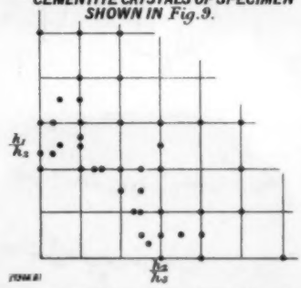


FIG. 11. PHOTOGRAM OF CEMENTITE CRYSTALS FROM COMPACT PORTION OF SPECIMEN SHOWN IN FIG. 9.

Fig. 12. GNOMONIC PROJECTION OF CEMENTITE CRYSTALS OF SPECIMEN SHOWN IN Fig. 9.



compact mass spiegel iron gave identical Laue photograms.

From the Laue photogram may be deduced the angles and the ratio of axes of the elementary parallelepiped as well as approximately its absolute dimensions.† The computation in this case gave an orthorhombic parallelepiped with a ratio of axes.

$$a_1 : a_2 : a_3 = 0{\cdot}673 : 0{\cdot}758 : 1.$$

a_3 is perpendicular to the developed surfaces, and its size was found to be about 7 Å.U.

From the Laue analysis of the problem it is obvious that all lines corresponding with the simplest combinations of indices in the quadratic formula are missing in the Debye photogram. Consequently the lines could not be identified on the basis of the not quite accurately determined dimensions, deduced from the Laue photograph.

For this reason a crystal plate was exposed in a Debye camera, in which it was slowly rotated about one of its axes. The spots on the photogram, situated in a plane that contains the incident X-ray beam and is perpendicular to the rotation axis, evidently are reflected from plane series parallel to this axis and consequently may easily be identified. The photograms‡ are given in Fig. 8, III to V, Plate XXV, as well as the indices corresponding to the quadratic formula at the spots in question. On the basis of the information obtained in this manner the dimensions of the elementary parallelepiped were found to be

$$a_1 = 4{\cdot}53 \text{ Å U.}; \; a_2 = 5{\cdot}11 \text{ Å.U.}; \; a_3 = 6{\cdot}77 \text{ Å.U.}$$

corresponding to the following formula:

$$\sin^2 \frac{\theta}{2} = 0{\cdot}0454\, h_1^2 + 0{\cdot}0357\, h_2^2 + 0{\cdot}0207\, h_3^2.$$

The $\sin^2 \frac{\theta}{2}$ values of three different cementite photograms are given in Table XI, where they can be compared with the corresponding quantities computed according to the formula. D indicates the diameter of the film cylinder.

TABLE XI.—*Cementite (Carbon, 6·85 per Cent.; Iron, 92·3 per Cent.) and Spiegel Iron. Time of Exposure, 6 Hours.*

$\sin^2 \frac{\theta}{2}$. Cementite. D = 50 MM.	Cementite. D = 55 MM.	Cementite. D = 60 MM.	Spiegel. D = 55 MM.	Comp.	I.	$h_1h_2h_3$.	Radiation.
0·130	0·132	0·132	0·132	0·135	v.w.	112	K_β
0·159	0·157	0·162	0·162	0·163	m.	112	K_α
0·178	0·177	0·181	0·180	0·182	w.	200	K_β
0·185	0·184	0·188	0·188	0·184	w.	022	K_β
0·203	0·202	0·209	0·207	0·208	m.	121	K_α
0·212	0·211	0·217	0·216	0·217	m.	210	K_α
0·225	0·221	0·226	0·226	0·224	st.	022	K_α
0·234	0·232	0·235	0·238	0·238	m.	211	K_α
0·264	0·262	0·267	0·267	0·265	st.	113	K_α
0·294	0·292	0·297	0·299	0·299	w.	212	K_α
0·322	0·320	0·326	0·327	0·326	w.	004	K_α
0·341	0·339	0·345	0·345	0·344	v.w.	221	K_α
0·365	0·361	0·368	0·371	0·367	w.	130	K_α
0·384	0·384	0·388	0·392	0·388	v.w.	131	K_α
0·403	0·406	0·407	0·407	0·407	w.	114	K_α
—	0·428	—	—	0·430	v.w.	231	K_α
0·464	0·465	0·471	0·473	0·465	w.	311	K_α
—	0·507	0·500	—	0·508	v.w.	140	K_α
—	0·516	—	0·520	0 516	v.w.	313	K_α
0·527	0·520	0·523	0·530	0·523	m.	231	K_α
—	0·545	—	0·552	0·546	v.w.	015	K_α
0·558	0·557	—	0·575	0·564	v.w.	233	K_α
0·582	0·587	—	0·596	0·585	v.w.	232	K_α
	0·593	—	—	0·598	v.w.	400	K_α
0·618	0·612	0·618	0·623	0·617	m.	140	K_α
0·624	0·624	0·632	0·629	0·628	m.	313	K_α
0·686	0·682	0·687	0·691	0·687	st.	233	K_α
0·699	0·695	0·702	0·699	0·698	st.	142	K_α
0·726	0·723	0·726	0·731	0·726	st.	400	K_α
0·731	0·729	0·734	0·738	0·733	st.	006	K_α
0·753	0·750	0·755	0·762	{0·750 / 0·753}	st.	{331 / 240}	K_α
0·767	0·765	—	—	0·770	w.	314	K_α
0·780	0·778	0·780	—	0·782	w.	411	K_α
0·837	0·832	0·835	0·837	0·834	m.	242	K_α
—	0·843	—	0·854	0·843	v.w.	412	K_α
0·942	0·941	0·941	0·949	0·946	m.	413	K_α
0·956	0·956	0·956	0·960	0·958	st.	151	K_α

From the table it is obvious that the Debye photogram can, without any difficulty, be explained by the formula found. It should, however, be pointed out that this fact alone is not sufficient to prove the correctness of the formula, although the results obtained by the other methods are thus confirmed.

Under the supposition that the elementary volume contains four molecules Fe_3C, the specific weight of cementite is found to be 7·62 (the absolute weight of an oxygen atom = $16{\cdot}1{,}664 \cdot 10^{-24}$ grammes).

The statements as to the specific weight of cementite given in literature differ very much, and must be considered unreliable. Most cementite preparations investigated probably contain graphite. If, however, annealed carbon steels might be considered to consist of two phases (ferrite and cementite), practically insoluble in each other, the specific weight of cementite could be calculated from the variation of the specific weight of the steels with the carbon content. Levin and Dornhecker* have shown that the specific volume of steels with less than 1 per cent. carbon is very nearly a linear function of the carbon content. Their data give a value of 7·59 for the specific weight of cementite, which agrees well with the result of the X-ray measurements.

On account of the relatively great number of atoms in the elementary volume of cementite, it is a difficult task to determine their grouping. This problem is yet unattacked, but might possibly be solved in the future.

Summary.—(1) X-ray photograms (according to Debye and Scherrer) of an iron wire, heated to 800 deg., 1,100 deg. and 1,425 deg. C. have shown that the iron within the so-called β and δ-ranges has a body-centred cubic structure and within the γ-range a face-centred cubic structure. The strange fact is thus proved, that the transformation that takes place at 900 deg. C. (A3) is reversed at 1,400 deg. C. (A4).

(2) The γ-iron lattice of austenite steels is enlarged by the dissolved carbon. A steel with 1·98 per cent. carbon has been found to have a somewhat larger lattice when quenched from 1,100 deg. C. than when quenched from 1,000 deg. C. Also the α-iron lattice in martensite seems to be influenced by the carbon present.

(3) The ranges of homogeneous α-iron lattice in martensite have proved to be extremely small. It has been stated that a steel with 0·80 per cent. carbon, quenched in water from 760 deg. C., is on the verge of being totally amorphous.

(4) Debye photograms of cementite and of the well-

* *Göttinger Nachrichten*, Sitzg., 26 Juli, 1918; R. Zsigmondy, *Kolloidchemie*, 3. Aufl., Leipzig, 1920, page 387.

† *Chemische Krystallographie*, I, Leipzig, 1906, pages 53, 56 to 58.

‡ *Monatsber. Akad. Berlin*, 1863, page 190.

§ *Tschermaks min. u. petr. Mitteil.*, 1903, vol. xxii, page 497.

‖ *Bull. Soc. Min.*, Paris, 1878, vol. ii, page 47.

¶ *Mineralogical Magazine*, London, 1903, vol. xiii, page 296.

** Mallard, *Bull. Soc. Min.*, Paris, 1889, vol. xii, page 421.

†† L. J. Spencer, Journal of the Iron and Steel Institute, 1901, No. I, page 79.

* The gnomonic projection = the projections of the poles of the reflecting planes on a plane perpendicular to the primitive X-ray beam. As to the elements of the Laue method, see Bragg, "X-Rays and Crystal Structure, London, 1916.

† Comp. P. Niggli, "Geometrische Kristallographie des Diskontinuums," Leipzig, 1919, page 512.

‡ The continuous lines are due to Fe_3O_4 coating the crystal, and a layer of α-iron, formed through decarbonisation.

* *Ferrum*, 1914, vol. xi, page 321.

known crystal tablets of spiegel iron have been found to be identical. A Laue photogram and investigations of an orientated rotating crystal of the latter type have made it possible to find out the crystal data of cementite. It belongs to the orthorhombic system, its ratio of axis is 0·670 : 0·755 : 1, and the dimensions of its elementary parallelepiped are 4·53, 5·11 and 6·77 Å.U. The base group consists of four molecules Fe_3C, which corresponds to a specific weight of 7·62 for the cementite.

The authors finally wish to express their gratitude to the Board of the Stockholms Högskola and Ingeniörsvetenskapsakademien in Stockholm for having kindly granted the sums necessary for an X-ray installation without which these investigations would have been impossible.

THE INNER STRUCTURE OF THE PEARLITE GRAIN.*

By Colonel N. T. BELAIEW (London).

I. *Introduction.*—The author's researches† on crystallisation of steel† were greatly facilitated by the fact that they were conducted on a series of alloys specially prepared at works in Russia under conditions of extremely slow cooling. About 60 hours were spent for an alloy to cool down with the furnace from 1,300 deg. to 300 deg. C., so that the areas of primary and secondary crystallisation were passed at a very slow speed. Accordingly, the structures corresponding were fully developed, often macroscopic, and easily lent themselves to examination. About 10 alloys with varying carbon content, from 0·45 per cent. to 1·80 per cent., were prepared in this way in 1907. In a previous paper delivered before this Institute* some of such alloys were referred to and their structures described.†

Table I gives the chemical composition and structure of some of these alloys.

TABLE I.

No.	C.	Si.	Mn.	P.	S.	Works.	Structure.
1	1·80	0·30	0·15	0·026	0·022	Poutiloff	Large crystals.
5	0·62	0·51	0·14	0·024	0·019	Poutiloff	Network.
8	0·55	traces	0·30	0·020	0·021	Ijewsky	Widmanstätten.

The alloys Nos. 1 and 5, made at the Poutiloff Works, were prepared under the author's personal supervision and a graph of cooling was taken. It may be interesting to note that the interval of 100 deg. between 750 deg. and 650 deg., that is, the interval comprising the Ar1 transformation, was passed by these alloys in 6 hours, or at the very low speed of 16 deg. or 17 deg. per hour, thus affording highly favourable conditions for undercooling and a subsequent development of coarse laminated pearlite.

The pearlite of the alloys Nos. 1 and 5 proved to be very well developed indeed, being discernible, in some grains at least, at magnifications between 30 and 50. There was, however, nothing exceptional in this, for in blister steel pearlite is sometimes equally well developed. The problem of getting a pearlite, discernible to the naked eye, of the magnitude of plessite in meteorites, still seemed very distant. The comparative failure of the experiment proved, however, to be a blessing in disguise, as it made the author, so to say, "hunt" for areas of coarse pearlite over large areas of slides. That "hunt" however, made him soon realise that in a sample of steel subjected to the same thermal treatment there is a great difference in the coarseness of pearlite in various grains.

As it seemed difficult to assume that thermal conditions could widely differ in samples slowly cooled down together with the furnace, the author tried to seek another explanation of the apparently puzzling fact that the distance between the cementite lamellæ could vary in adjacent grains sometimes in a ratio of 1 to 10, or even 1 to 15.

The study of the Widmanstätten structure had already shown the author the importance of crystallographic relations "in space," and made him, so to say, predisposed to look for "stereometric" relations. His task was, moreover, facilitated by reading Dr. Arnold's paper on "Practical Problems in the Metallography of Steel."* In that paper, Dr. Arnold insists on the importance of what he calls "the solid geometry of steel," and as an example takes the case of sulphide of manganese, giving, instead of one section, three: The transverse, the longitudinal vertical, and the longitudinal horizontal.†

Looking at the cementite lamellæ from such a point of view, and assuming that a secant plane would meet a multitude of grains under all kinds of angles, the author came to the conclusion that "the coarseness of pearlite, besides the actual size of cementite lamellæ and the distance between them, will depend on the position of the secant plane, as what we actually see is a projection of the lamellæ on that plane. Therefore, all other conditions being equal, pearlite of a certain degree of development will be the better seen on the slide the smaller the angle between the former and the longest axis of the cementite lamella."‡

For various reasons, the author was unable to resume these researches until the autumn of last year, when, thanks to the kindness of Dr. Carl Benedicks, who returned to him two samples of his alloys Nos. 1 and 8, and of Dr. Desch, who kindly prepared for him an alloy of eutectoid composition, he was in a position to continue, with the skilful collaboration of Captain Brandt, his researches on the inner structure of the pearlite grain.

II. *The Process of Granulation.*—A crystalline grain is an allotriomorphic crystal; that is, a crystal the external shape of which bears no relation to its internal symmetry. When a substance begins to crystallise and a new phase is being deposited, this process starts simultaneously from several centres or nuclei. The number of grains and their dimensions depend on the number of nuclei and on the linear velocity of crystallisation. The larger the former and the smaller the latter, the greater will be the number of grains. If we assume that the nuclei are evenly distributed and the linear velocity of crystallisation is one and the same from every nucleus, then in the first instance spheres will ensue from

Diagram 1. EQUILIBRIUM DIAGRAM.

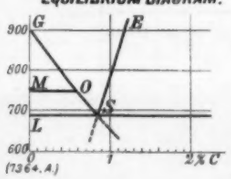


Diagram 2. A QUADRANT SECTION OF AN IDEAL PEARLITE GRAIN.

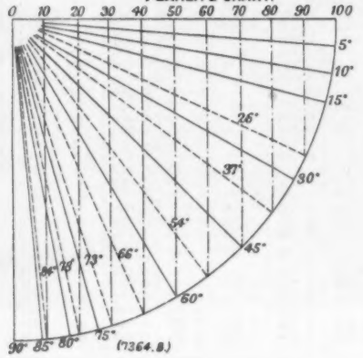


Diagram 3. A TRANSVERSE SECTION OF A PEARLITE GRAIN.

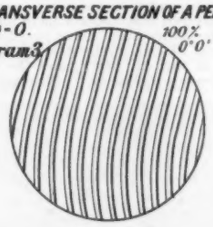


Diagram 4. CONSECUTIVE SECTIONS AT INCREASING ω's. (½ SCALE OF Diag. 3.)

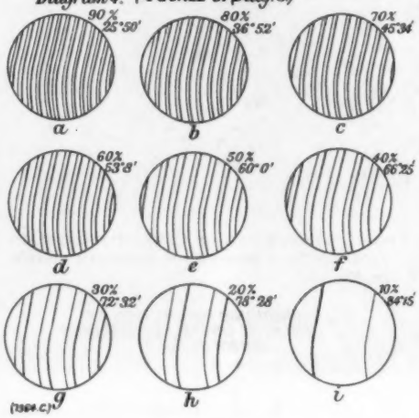


Diagram 5. A DRAWING OF A SECTION. ω = 0.

Diagram 6. A DRAWING OF A SECTION. ω = 84.

Diag. 7. A TRANSVERSE SECTION OF CEMENTITE LAMELLÆ.

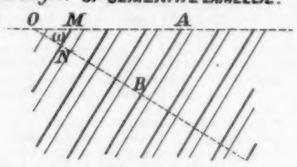
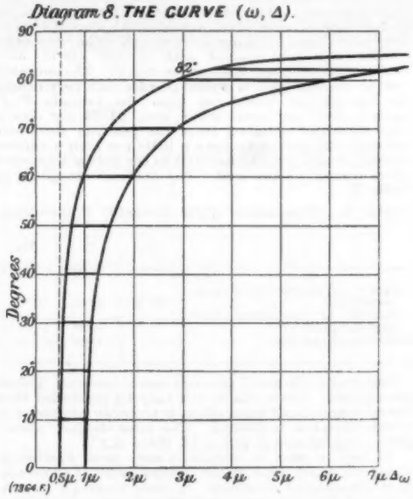


Diagram 8. THE CURVE (ω, Δ).



* Paper read before the Iron and Steel Institute, May 5, 1922.

† "Crystallisation, Structure and Properties of Steel on Slow Cooling." Thesis. Petrograd, 1909 (Russian), and "Sur la Cristallisation et Structure des Aciers refroidis lentement," *Revue de Métallurgie*, 1912, page 321 (first three chapters of the Thesis). See also "The Structure of Steel," a lecture delivered to the Institution of Aeronautical Engineers on October 27, 1920, and published in the Journal of the Institution, 1920, vol. i, No. 3, page 14.

* "Damascene Steel," Journal of the Iron and Steel Institute, 1918, No. I, page 425.

† *Ibid.*, "The Structure of Steel," Part II.

* *Metallographist*, 1902, vol. v, page 228.

† *Ibid.*, page 231; reproduced in the author's Thesis, page 37.

‡ Thesis, page 37.

X-RAY STUDIES ON THE CRYSTAL STRUCTURE OF STEEL.

(*For Description, see Page* 630.)

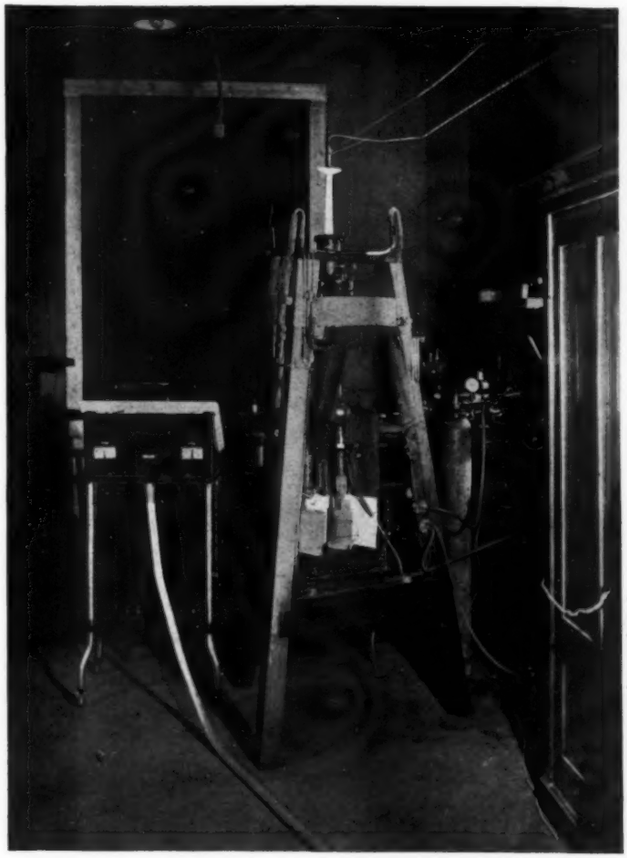


FIG. 1. FRONT VIEW OF APPARATUS.

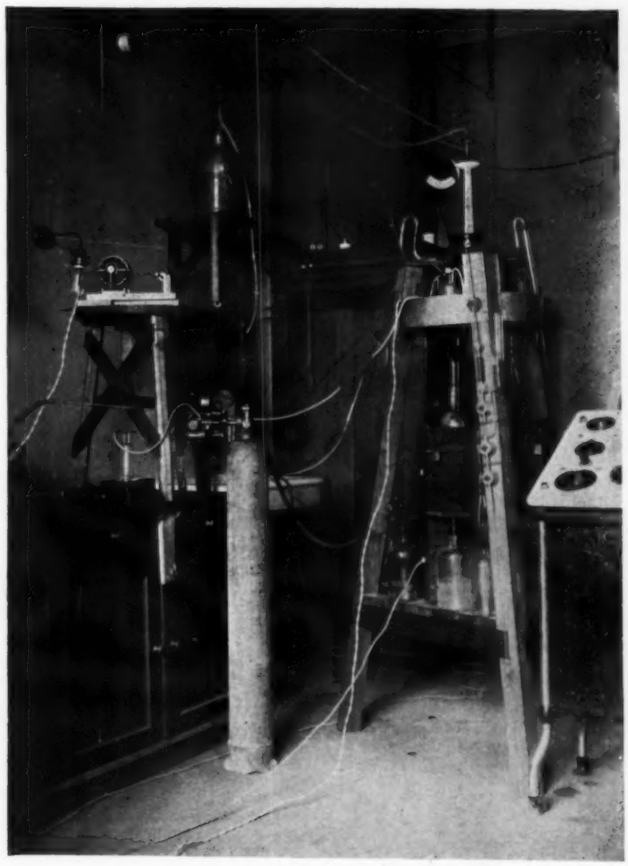


FIG. 2. BACK VIEW OF APPARATUS.

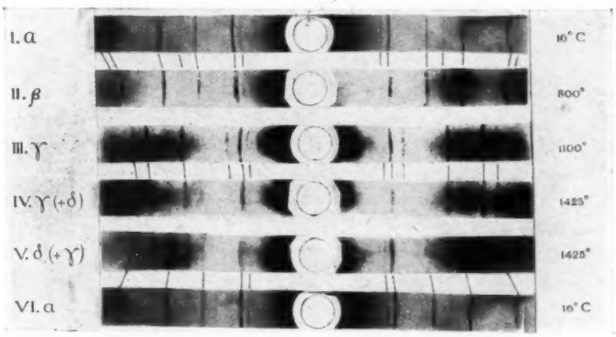


FIG. 4. PHOTOGRAMS OF CRYSTAL STRUCTURE OF PURE IRON.

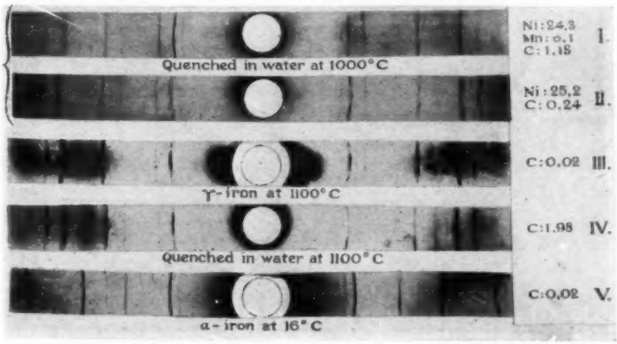


FIG. 6. PHOTOGRAMS OF NICKEL STEELS AND CARBON STEELS.

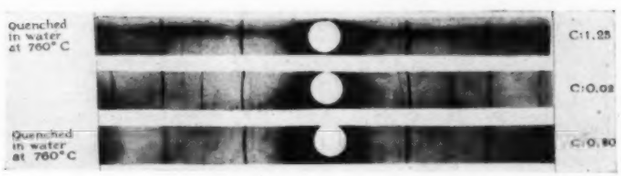


FIG. 7. PHOTOGRAMS OF CARBON STEELS AND PURE α-IRON.

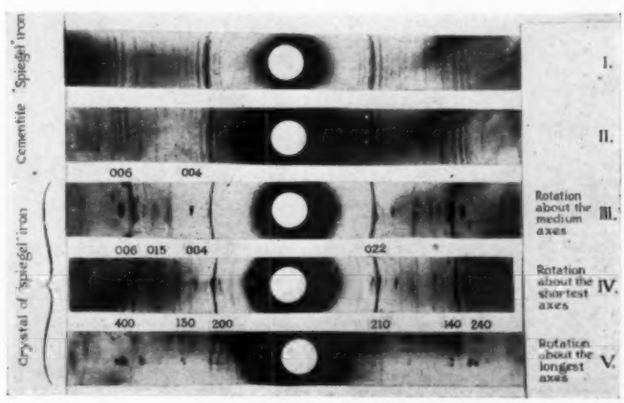


FIG. 8. COMPARATIVE PHOTOGRAMS OF SPIEGEL IRON AND CEMENTITE POWDER.

(*To face page* 634.)

THE INNER STRUCTURE OF THE PEARLITE GRAIN.

(*For Description, see Page* 634.)

Fig. 1. Alloy N_8. $\omega = 78°$. × 3500.

PEARLITE.

Fig. 2. Alloy N_1. $\Delta_o = 1{\cdot}25\ \mu$. × 250.

Fig. 3. Alloy N_8. $\Delta_o = 0{\cdot}35\ \mu$. × 1000.

PEARLITE.

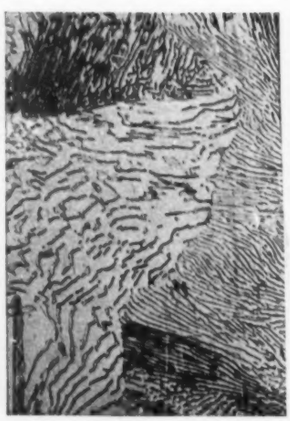


Fig. 4. Alloy N_1. $\Delta_o = 1{\cdot}25\ \mu$. × 250.

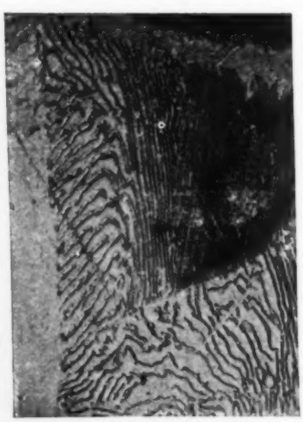


Fig. 5. Alloy N_8. $\Delta_o = 0{\cdot}35\ \mu$. × 1000.

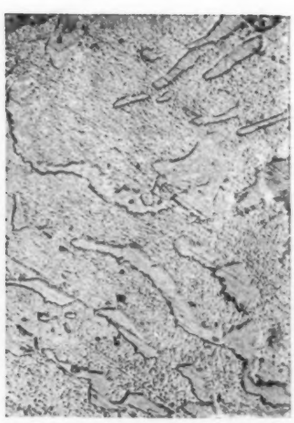


Fig. 6. Alloy N_1. $\omega = 83°$. × 1000.

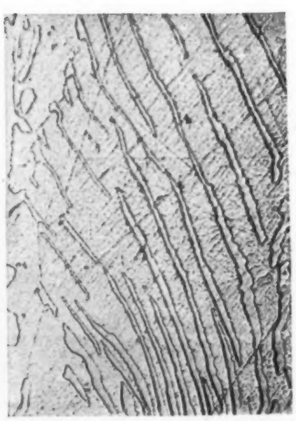


Fig. 7. Alloy N_1. $\omega = 74°$. × 1000.

PEARLITE.

THE INNER STRUCTURE OF THE PEARLITE GRAIN.

(*For Description, see Page* 634.)

FIG. 8. ALLOY N_8. $\omega = 80°$. × 2000.

FIG. 9. ALLOY N_1. $\omega = 83°$. × 2000.

PEARLITE.

FIG. 10. ALLOY N_8. $\Delta_o = 0{\cdot}35\ \mu$ $\omega = 82°$. LEITZ. APOCHROMATE 2 MM. N.A. = 1·32. × 4500.

"STEPS OF PEARLITE."

FIG. 11. ALLOY N_{21}. $\omega = 86°$ $\epsilon = 4°$. × 2400.

FIG. 12. ALLOY N_{21}. $\Delta_o = 0{\cdot}30\ \mu$ $\omega = 86°$. × 3000.

PEARLITE.

THE INNER STRUCTURE OF THE PEARLITE GRAIN.

(*For Description, see Page* 634.)

FIG. 13. ALLOY N_8. $\omega = 80°$. $\epsilon = 10°$. × 4000.

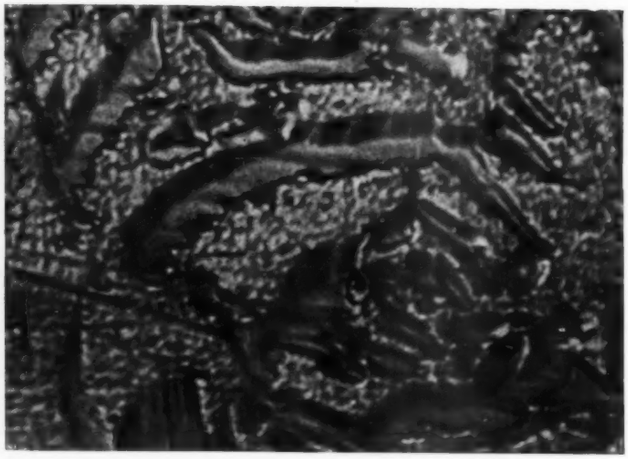


FIG. 14. ALLOY N_{21}. $\omega = 87°$ $\epsilon = 3°$. × 4000.

PEARLITE.

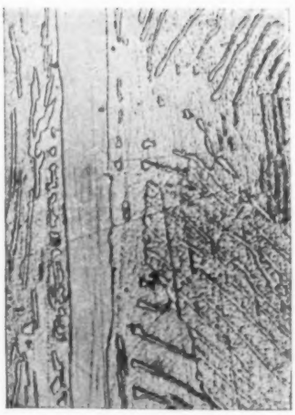


FIG. 15. ALLOY N_1. × 1000.

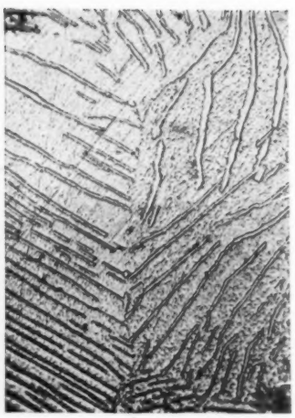


FIG. 16. × 1000.

FIG. 17. $\Delta_o = 1{\cdot}25\mu$. × 1000.

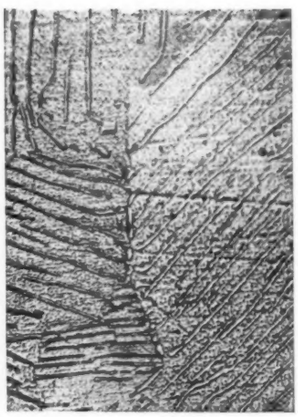


FIG. 18. × 1000.

PEARLITE.

FIG. 19. ALLOY N_1 × 1000.

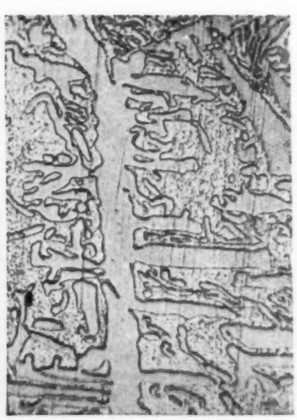


FIG. 20. × 1000.

FIG. 21. × 1000.

FIG. 22. × 1000.

PEARLITE AND CEMENTITE.

(*To face page* 635.)

every nucleus, and their number will be equal to the number of nuclei. The next stage will be that of spheres beginning to meet and boundaries being produced. Finally the whole volume will be evenly distributed between nuclei in polyhedral grains.

As shown by Professor Desch, such ideal polyhedra will be either rhombic or trapezoidal dodecahedra, according to the packing of the spheres. Actually the process is more complex, and it is difficult to state definitely whether metal grains would always tend to assume such form. It is important to note, however, that isolated granules of different metals and alloys, as well as polygonal sections on slides, clearly show that the shape of the grain does not depend on the crystallographic properties of the crystallising substance, but on the conditions of the process. This accounts for the fact that the polyhedral structure of different metals and alloys is very similar. For instance, the structure of pure copper resembles that of pure gold, and both exhibit exactly the same features as the structure of gamma-iron.

III. *The Pearlite Grain.*—The author is inclined to think that the formation of pearlite during the Ar1 transformation proceeds exactly on the same lines, that is, that nuclei are formed and from these a crystallographic rearrangement proceeds with a certain linear velocity. In this way new alpha-iron grains are being built up. Simultaneously with that rearrangement cementite lamellæ are being thrown out and the formation of pearlite goes on apace. Every crystallisation necessitates a certain undercooling, when, graphically, the alloy is brought beneath the transformation line. In the case of a eutectic (or eutectoid) the alloy will be supersaturated simultaneously with regard to both components. To make this last point clear, let us take the case of pearlite (diagram 1). Every alloy of eutectoid composition or of a composition sufficiently close thereto, when undercooled will be brought not only beneath the line L S, but also beneath the dotted parts of the lines E S and G O S. Every alloy to the right of the line E S will be supersaturated with regard to cementite; every alloy to the left of G O S will be supersaturated with regard to ferrite. Therefore, every alloy brought simultaneously to the right of E S and to the left of G O S will be supersaturated with regard to both components.

Let us assume that when crystallisation starts a particle of cementite is thrown our first; the supersaturation of the remaining mass with reference to ferrite will increase. Therefore, a corresponding amount of ferrite must be thrown out—and so on. Oscillating between the two, the whole grain will undergo the transformation and finally show alternate layers of cementite and ferrite. These layers or scales will lodge themselves, as is usually the case, with secondary deposits, parallel to the crystallographic planes of the crystalline mass of the grain. As alpha-iron crystallises in cubes, we may assume that these layers will arrange themselves parallel to the faces of the cube. As the orientation of later lamellæ is predetermined by the first, all will lodge themselves parallel to the one face "selected" by the first deposit. Let us imagine a pack of cards in a square-sided box. This will illustrate the "packing" of lamellæ in a grain. We may further suppose, instead of one pack of cards, two dissimilar packs, a card of each pack alternating with the other. Such an arrangement will give an idea of the alternate scales of ferrite and cemetite.

IV. *Stereometry of the Pearlite Grain.*—Let us assume that a sphere is inscribed in a polyhedral grain, and lamellæ of cementite and ferrite are closely packed in that sphere parallel with one another and with the first meridian. An equatorial section will then be perpendicular to the lamellæ. The edges of the lamellæ will show series of equidistant parallel lines. If the total number of lamellæ in the sphere be 200, a quadrant section will show 100 of these, and 100 lines will be seen on a section. The appearance will be that of idealised, "closely packed" pearlite.

Let us now consider a section inclined to the equatorial plane at an angle of ω, equal to 26 deg. As diagram 2 shows, 90 instead of 100 lamellæ will appear; the apparent thickness and the distance between the lamellæ will slightly increase (by 10 per cent.), and the pearlite will seem just a little less closely packed (diagram 4, *a*). Consecutive sections at 37 deg., 45 deg. and 54 deg. will respectively show 80 per cent., 70 per cent. and 60 per cent. of all the lamellæ (diagram 4, *b*, *c*, *d*). A section at an angle of 60 deg. will show only 50 per cent. of lamellæ, the distance between them increasing in the ratio of two to one (diagram 4, *e*). Still, the character of the grain will remain much the same and the "pearlite" will seem only less closely packed. The same applies to the section 66 deg. (diagram 4, *f*). Only the next sections of 73 deg. and 78 deg. begin to look sufficiently "coarse" (diagram 4, *g* and *h*) to make us call such a pearlite a "well-developed" one.

Lastly, a section inclined at an angle of 84 deg. will show only 10 per cent. of lamellæ (diagram 4, *i*), and the picture as shown by microsections becomes a rather peculiar one.

To make this point more clear, on diagrams 5 and 6 two sections of a pearlite grain are drawn. On diagram 5 the angle of inclination ω is 0 deg., and 40 lamellæ are seen. On diagram 6 only 4 out of 40 (or 10 per cent.) are visible. The angle of inclination is therefore 84 deg. The two diagrams, while still "idealised," are drawn from actual grains. They show how pure and simple "stereometric" relations may entirely alter the familiar aspect of the pearlite grain. They also show how the angle of inclination ω may be computed from the number N of cementite lamellæ in the grain.

V. *Determination of the Values of the Angle ω.*—As already mentioned, ω is the angle of inclination of the secant plane, *i.e.*, the angle between that plane and the equatorial section. The position of a plane in space is determined by two angles, the angle of inclination of the plane to the axial plane—say, to the plane X O Y, and the angle of deviation, *i.e.*, the angle between the axis O X and the trace of the secant plane on the axial plane X O Y. Let the axial plane coincide with the equatorial plane, then the angle of inclination will be ω; let us denote the angel of deviation by ϕ.

Let us consider first sections such that $\phi = 0$, that is, symmetric sections. Then the position of the section in space will be determined by the values of ω.

Let us further denote the distance between two adjacent cementite lamellæ by Δ. The apparent distance between them on a section inclined at an angle ω will be Δ_ω. As the distance between two planes is measured on a normal plane, and as the angle of inclination of such a plane is 0, we may denote the actual distance between two lamellæ by Δ_0. Let a series of parallel lamellæ be cut by a secant plane at an angle ω (diagram 7).

For the triangle A O B we have the following relations:

$$\cos\omega = \frac{O\,B}{O\,A} \text{ and } \sec\omega = \frac{O\,A}{O\,B}$$

but O B = 4 O N and O A = 4 O M, where O N = Δ_0, O M = Δ_ω. Therefore

$$\cos\omega = \frac{\Delta_0}{\Delta_\omega},\ \sec\omega = \frac{\Delta_\omega}{\Delta_0}$$

The values of Δ_0 and Δ_ω might be easily computed in the following way:

Let D be the mean diameter of a pearlite grain, and N the number of lamellæ. Then

$$\Delta_0 = \frac{D}{N}$$

Let n be the number of lamellæ on a section, then

$$\Delta_\omega = \frac{D}{n}$$

therefore

$$\frac{\Delta_0}{\Delta_\omega} = \frac{n}{N}$$

As the number of lamellae on a section is actually taken not with reference to the grain, but to a chosen linear unit, we may say that:

The distances between lamellæ in two sections vary in the inverse ratio to their number shown on such sections.

As $\frac{\Delta_0}{\Delta_\omega} = \cos\omega$, we may say that

$$\cos\omega = \frac{n}{N}$$

VI. *Numerical Values of Cos ω.*—Let us take the equation

$$\cos\omega = \frac{n}{N}$$

It follows that the ratio $\frac{n}{N}$ might be determined by the graph of natural cosines. We may say, therefore, that the decrease in the number of lamellæ, or the increase in the coarseness of pearlite, are slow at small angles of inclination, but begin to increase rapidly afterwards.

To make these relations clear the corresponding values of angles of inclination ω, natural cosines, cos ω, and of the number of lamellæ n, are tabulated below (Table II).

TABLE II.

ω.	Cos ω.	n.	δn.	$\Sigma\delta n$.
deg.				
0	1·00	100	—	—
10	0·98	98	2	2
20	0·94	94	4	6
30	0·87	87	7	13
40	0·77	77	10	23
50	0·64	64	13	36
60	0·50	50	14	50
70	0·34	34	16	66
80	0·17	17	17	83

In the last two columns the decrease of the number of lamellæ per 10 deg. δn and the cumulative decrease $\Sigma\delta n$ are shown. If we take N = 100, then the values of the columns 3 and 5 may be taken as percentages. As the increase of $\Sigma\delta n$ becomes very marked for larger ω's, the same values are computed in Table III through 1 deg.

The values of ω can also be computed from the equation

$$\cos\omega = \frac{\Delta_0}{\Delta_\omega}$$

As the Δ's are easily measured on photomicrographs, this formula seems to be best suited for practical purposes.

Actual determination of the distance between two lamellæ Δ, usually gives values below 1¼ of a millimillimetre (μ). Only in exceptional cases does that value increase to 3 μ. In Table IV, the values of Δ_ω are computed for seven decreasing values of Δ_0: 3, 2, 1·50, 1·25, 1, 0·50 and 0·25 μ.

The figures of columns (*e*) and (*f*) corresponding to $\Delta_0 = \mu$ and $0{\cdot}5\,\mu$ are represented in diagram 8, where the graph (ω, Δ) is given.

Tables II, III, and IV, together with diagrams 2, 3, 4, 5, 6, and 8, may serve to explain how and why the general appearance of a pearlite grain undergoes a considerable change in one and the same specimen, often within the same photomicrograph.

They may also serve as an indication that only at angles of inclination close to or exceeding 80 deg. would the aspect of the pearlite grain be entirely altered, so as to exhibit sometimes quite unexpected features. It follows also that on a slide where a sufficiently large number of grains are seen, approximately only one-tenth will belong to this last category.

VII.—*The Pearlite of Prepared Alloys.*—To test the conclusions of the preceding paragraphs, let us investigate the pearlite of the alloys prepared at slow cooling. From the alloys mentioned in Table I, three samples were investigated, one from No. 1 and two from No. 8. To these a sample of eutectoid steel, kindly prepared for that purpose by Professor Desch, was added. In the first instance the distance between the cementite lamellæ, Δ_0, was determined for every alloy. The results are given in Table V.

It may be taken from Table V that

$$(\Delta_0) = 4\,(\Delta_0)\ 21$$
$$(\Delta_0) = 3,\ 6\,(\Delta_0)\ 8$$

or that roughly the pearlite of the alloy No. 1 is four times coarser than that of alloys Nos. 8 and 21.

TABLE III.

ω.	Cos ω.	n.	$\Sigma\delta n$.
60	0·500	50·0	50·0
61	0·485	48·5	51·5
62	0·470	47·0	53·0
63	0·454	45·4	54·6
64	0·438	43·8	56·2
65	0·423	42·3	57·7
66	0·407	40·7	59·3
67	0·391	39·1	60·9
68	0·375	37·5	62·5
69	0·358	35·8	64·2
70	0·342	34·2	65·8
71	0·326	32·6	67·4
72	0·309	30·9	69·1
73	0·292	29·2	70·8
74	0·276	27·6	72·4
75	0·259	25·9	74·1
76	0·242	24·2	75·8
77	0·225	22·5	77·5
78	0·208	20·8	79·2
79	0·191	19·1	80·8
80	0·174	17·4	82·6
81	0·156	15·6	84·4
82	0·139	13·9	86·1
83	0·122	12·2	87·8
84	0·105	10·5	89·5
85	0·087	8·7	91·3
86	0·070	7·0	93·0
87	0·052	5·2	94·8
88	0·035	3·5	96·5
89	0·018	1·8	98·2

TABLE IV.

Cos ω	ω.	n.	Δ_ω.						
			a.	*b*.	*c*.	*d*.	*e*.	*f*.	*g*.
	deg. min								
1·0	0 0	100	3·00	2·00	1·50	1·25	1·00	0·50	0·25
0·9	25 50	90	3·30	2·22	1·67	1·39	1·11	0·55	0·27
0·8	36 52	80	3·75	2·50	1·87	1·56	1·25	0·62	0·31
0·7	45 34	70	4·29	2·86	2·14	1·79	1·43	0·71	0·36
0·6	53 8	60	5·00	3·33	2·50	2·08	1·67	0·83	0·41
0·5	60 0	50	6·00	4·00	3·00	2·50	2·00	1·00	0·50
0·4	66 25	40	7·50	5·00	3·75	3·12	2·50	1·25	0·62
0·3	72 32	30	10·00	6·66	5·00	4·17	3·33	1·67	0·83
0·2	78 28	20	15·00	10·00	7·50	6·25	5·00	2·50	1·25
0·1	80 15	10	30·00	20·00	15·00	12·50	10·00	5·00	2·50
0·05	87 15	5	60·00	40·00	30·00	25·00	20·00	10·00	5·00

TABLE V.

No.	Composition.	Structure.	Δ_0
1	Hypereutectoid ..	Large crystals ..	1·25
21	Eutectoid ..	Network ..	0·30
8	Hypoeutectoid ..	Widmanstätten ..	0·35

On Figs. 2 and 3, Plate XXVI, are shown two pearlite areas of similar character, one from alloy No. 1, the other from alloy No. 8. The two figures follow one another pretty closely, but whilst the magnification of Fig. 2 is only 250, that of Fig. 3 is 1,000. As the ratio of 1,000 to 250 is 4, we may see that from the ratio of the Δ_0's a correct inference may be drawn as to the general appearance of pearlite on a slide. In this particular case the pearlite of Fig. 2 seems a little coarser than that of Fig. 3, but that is accounted for by the fact that the angles ω in Fig. 2 vary only within the limits of 40 deg. to 80 deg., whereas in Fig. 3 they vary from 0 deg. to 70 deg.

Figs. 4 and 5, may further serve to illustrate this conclusion. On Fig. 4 (alloy No. 1) a large grain, inclined at the angle ω of 81 deg., is surrounded by smaller grains, their ω's being 62 deg., 39 deg., and 20; the magnification is 250. On Fig. 5 (alloy No. 8) the respective ω's in the left half of the picture are 78 deg. and 60 deg. Both photographs are very much alike, but to make the apparent distances equal in similar grains, the magnification of Fig. 5 had to be brought up to 1,000.

Figs. 6 and 7 show what the alloy No. 1 would look like at a magnification of 1,000. On Fig. 6 a spot is shown, where ω = 83 deg.; on Fig. 7, where ω = 74 deg. The comparison of these two figures shows that within the 10 deg. comprising 74 deg. and 83 deg. an enormous change in the appearance of cementite lamellæ takes place. Whilst the lamellæ of Fig. 7 still run more or less parallel one to another at regular intervals, those of Fig. 6 are oddly shaped and their curvature is more

pronounced. As the angle between the section and the lamella (let us call that angle ϵ) is very acute,* one border of the lamella seems darker, and even more abrupt, than the other. The whole picture begins to look like a bird's-eye view of an anticline. The etching figures on ferrite are also fairly well developed. They are perhaps a little better seen on Fig. 9, where the same lamellæ are taken at a magnification of 2,000.

On Fig. 8, an analogous section of the alloy No. 8 is shown under the same magnification of 2,000. The angle of inclination ω for that section is 80 deg., and therefore the supplementary angle ϵ is 10 deg. In spite of the fact that ϵ for the section of Fig. 9 is still lower, being, as just mentioned, only 70 deg., the ferrite lamellæ are very well developed, whereas their complete absence on Fig. 8 will be easily noted. As just mentioned, the etching figures on the alloy No. 1 are sufficiently well developed. The author tried by prolonged etching to bring them also into evidence on one slide of the alloy No. 8; but the result, whilst quite logical, proved to be rather unexpected, as instead of more deeply etched lamellæ of ferrite there was no ferrite at all. A closer examination of Fig. 8 shows that all the ferrite of the large grain ($\omega = 80$ deg.), which on the "day surface" was exposed to the "weathering" influence of the etching medium, was literally washed away, leaving only here and there isolated "cubes" of the original mass and revealing "the steps" of cementite.

A small triangular grain to the right ($\omega = 60$ deg.) shows deep furrows of the etched-away ferrite, leaving only in relief the ridges of cementite lamellæ. Some of these on the top of the figure are interesting, as they show the actual structure of cementite films in pearlite.

Usually, an $\omega = 80$ deg. is not enough to expose the whole of even a small lamellæ, but here the deep etching is, so to say, "exaggerating" the visual effect of the angle of inclination.

A further comparison between the two figures shows the deep change in the aspect of cementite lamellæ which begins to become apparent when the angle ω increases to over 80 deg. On Fig. 8, for instance ($\omega = 80$ deg.), in spite of the accidental absence of ferrite, most of the lamellæ edges run roughly parallel, whilst on Figs. 6 and 9 ($\omega = 83$ deg.) the "exposed" edges are less parallel, mostly curved, and exhibit a broken aspect.

Fig. 10, may serve as a further illustration. Here is selected a section of the alloy No. 8 running under the angle of 82 deg., *i.e.*, practically at the same inclination as Fig. 9. In order to show all the details the magnification, however, had to be increased to 4,500.

The middle part of the plate is occupied by a band of cementite lamellæ running from the left top corner "in steps." But these steps are not so regular as those on Fig. 8. Both the "Brokenness" of the edges and the curvature of lamellæ is more pronounced.

Before proceeding further let us recapitulate some of the figures of Table III. These are retabulated in Table VI, for the angles 80 deg. to 89 deg. Two columns are added, one of natural secants and the other of Δ_ω. The Δ_ω are computed for $\Delta_0 = 1\,\mu$; their numeral values are therefore equal to corresponding secants.

TABLE VI.

ω.	Cos ω.	Sec ω.	$\Delta\omega$.	n.	ϵ.
deg.					deg.
80	0·174	5·8	5·8	17·4	10
81	0·156	6·4	6·4	15·6	9
82	0·139	7·2	7·2	13·9	8
83	0·122	8·2	8·2	12·2	7
84	0·105	9·6	9·6	10·5	6
85	0·087	11·5	11·5	8·7	5
86	0·070	14·3	14·3	7·0	4
87	0·052	19·1	19·1	5·2	3
88	0·035	28·7	28·7	3·5	2
89	0·018	57·3	57·3	1·8	1

As seen from this table the apparent distance between the lamellæ Δ_ω begins to increase at an accelerated pace after 87 deg., or even before, say, from 83 deg. to 84 deg., that increase becomes very marked. It may also be noted that at these inclinations every degree is of importance.

Now, if in the light of these figures we turn to Plate XXVII we see that Figs. 9 and 10 are inclined under $\omega = 83$ deg. and 82 deg., *i.e.*, quite close to such values as would cause a rapid increase Δ_ω and a consequent distortion of the picture.

In Figs. 11 and 12 two further sections are shown, both corresponding to $\omega = 86$ deg. The lamellæ of Fig. 11 (× 2,400) exhibit the "brokenness" of edges in the highest degree. Those of Fig. 12 (× 3,000) perhaps allow of the structure being seen a little better, as some of them seem to lie quite close to the plane of the section, the angle ϵ being only 4 deg. Both of these lamellæ clearly show the cleavage planes and the crystallography of cementite.

It remains to explore only 4 deg. The pictures become so distorted and the measurements so difficult however, that for the present the author is rather averse to committing himself further. Perhaps, however, Fig. 14 would show a section of the eutectoid alloy under the angle of 87 deg. (× 4,000).

The cementite lamellæ bear here but a scant resemblance to their former selves on less adventurous sections. Caustic spirits might even question the identity of such a pearlite—but pearlite it is, and even laminated pearlite.

VIII. *Determination of* Δ_ω.—By Δ_ω we understand the apparent distance between two adjacent lamellæ of cementite, *i.e.*, the distance between the lamellæ on a section inclined under the angle ω. The Δ_ω is easily measured on a photomicrograph under a suitable magnification. For the purpose of resolving the very delicate structure of pearlite, objectives of high numerical aperture are essential. But once the structure resolved, it is advisable to magnify it sufficiently to make measurements easy. For this purpose in most pearlite steels the magnification of 1,000 may be considered as the standard one. It has also the incidental advantage of showing in millimetres every micron (μ) of actual dimensions. Once suitable photos are secured the next stage would be to select such portions of the grain where a certain number of lamellæ are seen to run more or less parallel to one another. Then the number of lamellæ on 10 mm. or 20 mm. may be counted and then the distance between two lamellæ determined in millimetres. If the magnification is 1,000 the actual units will be μ.

Figs. 15, 16, 17 and 18, exhibit various grains of pearlite of the alloy No. 1. They are very interesting in themselves, as, for instance, they clearly show the difference in levels of adjacent grains, and the author selected for measurement is inclined at either $\omega = 0$ or at any rate sufficiently close to it.

Let us examine a pearlite area under gradually increasing magnification. If the pearlite grains are as large as those of the alloys prepared, their boundaries may be seen even with the naked eye. At vertical illumination some of the grains would seem dark, the others bright. If oblique illumination be used a certain irridescence would be noted. As the magnification is raised to 30 or 40, some of the grains will begin to be dissolved into alternate layers of ferrite and cementite. Finally, by using an objective with high aperture a magnification would be obtained when the most reluctant grains would show their structure. The grains to show their structure last are the grains we need, as their angle of inclination ω is the lowest, possibly close to zero. If large areas of the slide had been examined and several of the "reluctant" grains tested, one might feel assured that the values of Δ_0 so determined were correct to a sufficient degree of accuracy.

FIG. 23. ALLOY N_1. × 100.

FIG. 24. × 250.

FIG. 25. × 1,000.

hopes to return to this subject at a later date. For our immediate purpose it is sufficient to remark that in nearly every grain there are sufficient parallel lamellæ to determine the Δ_ω with sufficient accuracy to give a general idea of the crystallographic orientation of various grains. The degree of accuracy of measuring Δ_ω largely depends on the character of the pearlite. In hyper and hypo-eutectoid steels great care must be taken not to be led astray by such areas of pearlite which lie too close to the pro-eutectoid element, and where their orientation depends not so much on the crystallography of the grain as on the "directive" impulse of the previous deposits. Figs. 19, 20, 21, and 22 of the alloy No. 1 may be taken as illustrations of that directive force.

IX. *Determination of* Δ_0.—As stated in Section V, the actual distance between two lamellæ was denoted as Δ_0, or in other words as such Δ_ω that the angle of inclination $\omega = 0$ and the section become normal to the lamellæ. The direct way to determine Δ_0 would seem to be the same as for the determination of Δ_ω, *i.e.*, to measure the distance between two lamellæ or to count the number of lamellæ per 1 cm. As long as Δ_0 is not less than μ the measuring or counting of lamellæ on a photomicrograph will be comparatively easy, but when Δ_0 sinks below $0{\cdot}5\,\mu$ or $0{\cdot}3\,\mu$, a magnification of 2,000 or 3,000, or even 4,000, becomes desirable. However, before counting the lamellæ some preliminary operations are necessary to make sure that the grain

Let us examine in that way the alloy No. 1. On Fig. 23, about 1 sq. mm. of that alloy is shown under a magnification of 100. As the carbon content of that alloy is 1·80 per cent. (Table I), pearlite occupies 83 per cent. and cementite the remaining 17 per cent. of the total area. The granulation of pearlite is clearly seen, as well as the striking differences in the coarseness of its structure even in adjoining grains. The grain in the centre of the picture has a very fine structure and was selected for the purpose of determining the Δ_0. That grain is easily identified as a long straight needle of free cementite runs straight across it. Parts of the same grain are shown on Fig. 24 (× 250), Fig. 25 (× 1,000) and Fig. 26 (× 3,000).

The distance between the lamellæ can be easily measured on the latter two figures (Nos. 25 and 26), and so it would seem that the value of Δ_0 could be obtained in the easiest way. But the errors in such measurements would be too great, therefore the procedure of counting the number of lamellæ per certain number of millimetres must be recommended. For instance, on Fig. 25, to the left of the needle, 40 lamellæ are found on 50 mm., which gives the distance between the lamellæ on that figure as 1·25 mm., or actually $1{\cdot}25\,\mu$. As we are looking for the minimum values of Δ, care must be taken to select suitable grains, or portions of grains.

The value $1{\cdot}25\,\mu$ was subsequently checked on other grains of the same specimen and was found to be the

* The angle ϵ is a supplementary angle to ω. For Fig. 6 $\epsilon = 90$ deg. − 83 deg., or 7 deg.

minimum figure, therefore we may take for the alloy No. 1,

$$\Delta_0\,(1) = 1{\cdot}25\ \mu.$$

Similar measurements were taken for the other two alloys, and the values $\Delta_0\,(8) = 0{\cdot}35\ \mu$ and $\Delta_0\,(21) = 0{\cdot}30\ \mu$ determined.

The last two Δ's if given in micromillimetres would read:

$$\Delta_0\,(8) = 350\ \mu\mu$$
$$\Delta_0\,(21) = 300\ \mu\mu.$$

As the distance between two cementite lamellæ Δ_0 comprises one cementite lamellæ and one ferrite lamella, we may say that

$$d_c + df = \Delta_0.$$

where d_c is the diameter of the cementite lamella, and

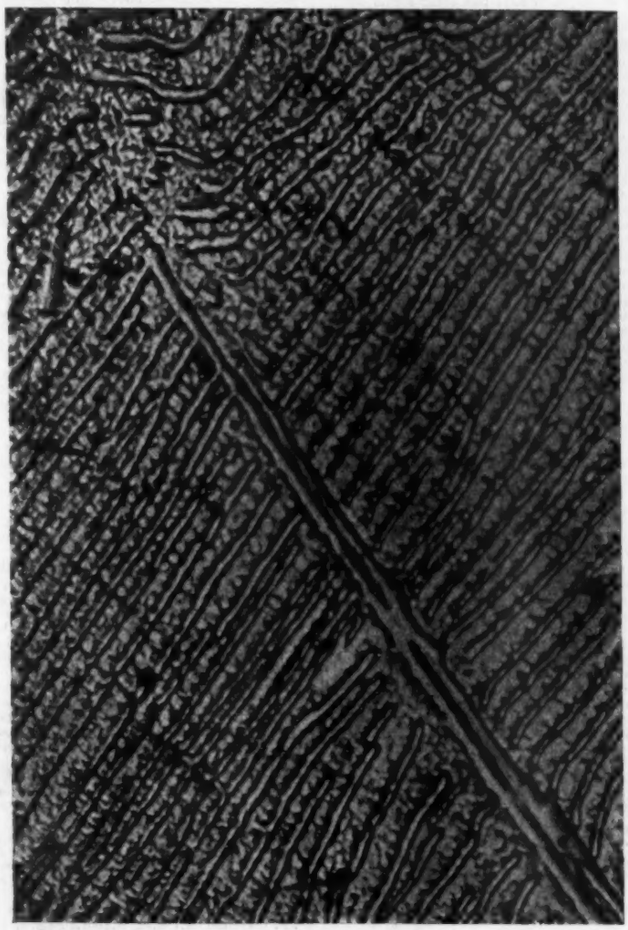


FIG. 26. ALLOY N_1; $\Delta_0 = 1{\cdot}25\ \mu$; $\omega = 0$. PEARLITE. × 3,000.

df of the ferrite lamella. As the ferrite lamella is usually two or three times thicker than the cementite lamella,

$$d_c = \tfrac{1}{3}\,\Delta_0 \text{ or } d_c = \tfrac{1}{4}\,\Delta_0.$$

For instance, for the eutectoid alloy No. 21,

$$d_c = 100\ \mu\mu \text{ or } 75\ \mu\mu.$$

The photomicrographs, on which the measurements of Δ_0's were effected, were made with a Leitz 2-mm. Apochromat with numerical aperture of 1·32. The resolving power of the lens is about 170 $\mu\mu$. That means that the diameter of the cementite lamellæ of the alloys Nos. 8 and 21 is considerably below that resolving power. In such case, according to Sir George Beilby,* we shall see an ill-defined line, the apparent width of which will depend on the aperture of the lens only. Taking this into consideration, let us compare the high magnification photomicrographs of alloys Nos. 1 and 8—Figs. 10 and 26 respectively. The diameter of cementite lamellæ on Fig. 10 when actually measured is about 1 mm. As the magnification is 4,500, that would correspond to 220 $\mu\mu$, whereas the actual diameter as just shown is about 100 $\mu\mu$.

On the other hand, the measurement of cementite lamellæ on Fig. 26 (× 3,000) gives about 330 $\mu\mu$, which corresponds well with the calculated value

$$d_c = \frac{1{\cdot}25}{3}\ \mu \doteq 400\ \mu\mu \text{ or}$$

$$d_c = \frac{1{\cdot}25}{4}\ \mu \doteq 300\ \mu\mu.$$

The foregoing explains why, on the other hand, the ferrite lamellæ on Fig. 26 seem to be more wide than those on Fig. 10.

X. *Some Practical Hints with Reference to* Δ.—The value of Δ_0 may be taken as a characteristic of the heat treatment of a pearlite steel. As explained, Δ_0 remains constant for the whole volume where the thermal conditions in the Ar1 interval are the same. The more uniform the heat treatment the more constant will be Δ_0. As for the local differences in the structure of neighbouring pearlite grains, these are accounted for, as explained above, by the difference of the angle of inclination. The author believes that a scale of Δ_0's could be worked out for several standard treatments. But the difficulty of direct determination of small Δ_0 will stand in the way. However, the Δ_0 of the alloy could be determined indirectly in another way. Let us take the equation—

$$\text{Cos } \omega = \frac{\Delta_0}{\Delta_\omega}$$

hence $$\Delta_0 = \Delta_\omega \cos \omega, \text{ or } \Delta_0 = \frac{\Delta_\omega}{\sec \omega}$$

Let us assume that ω is known, and Δ_ω measured, then Δ_0 will be determined too. For instance, let us take $\omega = 84$ deg., then cos 84 deg. = 0·1 and

$$\Delta_0 = \frac{1}{10}\ \Delta_\omega$$

As the sections corresponding to such ω's as 78 deg. to 80 deg., 84 deg. and 87 deg. are very characteristic, it will not be difficult with a little practice to say which of these values the ω of the section will lie closer to. As, on the other hand, the measurement of a coarser structure of Δ_ω will not be difficult, the value of Δ_0 would be easily computed as $\frac{1}{5}$, $\frac{1}{10}$, $\frac{1}{20}$ of Δ_ω.

To sum up, we may say that, instead of looking for the most "closely packed" grain, we may look for the grain with the coarser structure. In this way steels with $\Delta_0 = 50\ \mu\mu$, or even less, could be investigated, *i.e.*, steel with sorbitic pearlite and close to sorbite itself. The problem would be to find a grain, or grains, the structure of which would be sufficiently intelligible to allow of measurements.

As an illustration the author would like to refer to one of Sir Robert Hadfield's beautiful microphotographs of fine lamellar and sorbitic pearlite*. Let us consider, for instance, Fig. 8 (× 5000). For the large lamellæ on the top, $\Delta_\omega = \dfrac{2{\cdot}5 \times 1000}{5000}\ \mu = 0{\cdot}5\mu$

The general character of the section is that of 80 deg. to 82 deg., as the edges of cementite lamellæ run mostly parallel one to another and there is no marked distortion in the pearlite aspect. As sec. 80 deg. = 5·7 and sec. 82 deg. = 7·1, and $\Delta_0 = \dfrac{\Delta_\omega}{\text{sec. } \omega}$, the values of Δ_0 would be comprised between $\frac{1}{6}$ and $\frac{1}{7}$ of Δ_ω or $\dfrac{0{\cdot}5}{6}\ \mu$ and $\dfrac{0{\cdot}5}{7}\ \mu$, or, finally,

$$\Delta_0 \doteq (80 - 70)\ \mu\mu$$

If we made an error in determining the angle ω, say of 5 deg., *i.e.*, the correct value of ω, instead of 82 deg., would be closer to 78 deg., then

$$\sec 78 \text{ deg.} = 4{\cdot}7, \text{ and}$$
$$\Delta_0 \doteq 100\ \mu\mu.$$

Let us assume that the last figure of 100 $\mu\mu$ is correct. As the authors of the paper (Sir Robert Hadfield and T. G. Elliott) call their pearlite "fine lamellar and sorbitic," we may infer that the values of $\Delta_0 = 100\ \mu\mu$ may be taken as lying close to the demarcation line between the two varieties.

XI. *On the Structure of the Cementite Lamella.*—Let us now try to get a more concrete idea of what a cementite lamella is really like. As mentioned above, the diameter of a cementite lamella may be taken as one-half to one-third of a ferrite lamella. The author is inclined to think that the latter value will be more correct; then

$$d_c = \tfrac{1}{3}\ df, \text{ whence}$$
$$d_c = \tfrac{1}{4}\ \Delta_0.$$

For the alloys investigated, the values of d_c are tabulated below (Table VII). The corresponding values computed for Sir Robert Hadfield's and T. G. Elliot's steel are added for reference. As the pearlite of the alloy No. 1 is exceptionally coarse, we have to consider the lesser values. So we may say that the average thickness of a cementite lamella will be between 25 and, say, 100 $\mu\mu$. But these figures if not quite the magnitude of Faraday's thin gold leaf, are still very close to them. Perhaps, therefore, it would be better to think of the cementite lamellæ as films and not as plates.

TABLE VII.

N.	Δ_0.	Diameter of Cementite Lamellæ.	
		μ.	$\mu\mu$.
1	1·25	0·31	300
8	0·35	0·09	90
21	0·30	0·07	70
Sir R. Hadfield's and T. G. Elliot's ..	0·10	0·03	25

It may be mentioned that the average ratio of the diameter of the grain D to Δ_0 is of the magnitude of one hundred,

$$\frac{D}{\Delta_0} = 100$$

As the same ratio gives the number of lamellæ

$$\frac{D}{\Delta_0} = N$$

we may infer that the number of lamellæ in a grain is close to and of the magnitude of 100.

Let us imagine now an idealised pearlite of one hundred cementite films of the thickness of 100 $\mu\mu$, packed in alternate layers with ferrite lamellæ 300 $\mu\mu$ thick. As cementite is extremely brittle, being—according to Howe—like glass, we may picture these extremely thin and rigid films, so to say, embedded in a matrix of ferrite. We may expect that during deformations the ductile matrix of ferrite will act as a protective coating, and the brittle cementite films would be bent and deformed to a certain, perhaps a large, extent. The author thinks that this may be a plausible explanation of the curvature of cementite lamellæ in pearlite. As mentioned above, the formation of cementite lamellæ is going on simultaneously with the transformation of gamma-iron into alpha-iron. As a change of volume occurs during that transformation the cementite films become bent and distorted. It is interesting to observe that the free cementite particles are mostly needle-shaped and perfectly straight, and that when cementite lamellæ in pearlite are straight, they are close to free cementite, suggesting an earlier stage of crystallisation. As to the shape of the lamellæ, that is well illustrated by the photomicrographs. It may be mentioned perhaps that

* "Aggregation and Flow of Solids," by Sir George Beilby, F.R.S., 1921, London, page 14.

* "Photomicrograph of Steel and Iron Section at High Magnification." By Sir Robert Hadfield and T. G. Elliot. *The Microscope*, symposium, 1920, p. 156.

the curvature of lamellæ makes them look sometimes "cup" or "petal" like. The structure of lamellæ in the grain is sometimes perfectly revealed by a prolonged etching. Then on the boundaries of the grain deep ravines are washed through, and in these the other edges of lamellæ are shown (ϕ), so that instead of a row of parallel lines two sets of parallel lines forming right angles may be seen. Fig. 1, Plate XXVI, exhibits that phenomenon in a remarkable degree (ω = 78 deg., ϕ = 90 deg.).

The author wishes to express his thanks to Dr. Carl Benedicks for having placed at his disposal samples of the author's alloys Nos. 1 and 8, to Professor Desch for having prepared and put at the author's disposal a sample of eutectoid steel, to Sir Robert Hadfield for having put at the author's disposal a photograph of the steel with sorbitic pearlite, to Captain Brandt for his untiring assistance in preparing slides and taking photographs, and to Captain Dmitrieff for the drawing of several diagrams.

Summary.—1. The arrangement of cementite lamellæ in a pearlite grain is roughly parallel one to another and to the crystallographic plane of the grain, presumably to one face of the cube.

2. A secant plane perpendicular to that face will be normal to the lamellæ; the angle of inclination ω for that plane will be zero. All the (N) lamellæ of the grain will be seen on the normal plane. The distance between two lamellæ (Δ) on such a plane will be the actual distance, and is called Δ_0.

3. As the angle ω increases, the number n of lemellæ seen on a section of the same grain decreases and the apparent distance between two lamellæ Δ_ω increases. As

$$\text{Cos } \omega = \frac{n}{N} = \frac{\Delta_0}{\Delta_\omega}$$

the graph of natural cosines will show the ratio of decrease in the number of lamellæ and of the increase in the distance between the lamellæ or the coarseness of the structure of the grain.

4. The angle of inclination ω may be computed from the equation—

$$\text{Cos } \omega = \frac{\Delta_0}{\Delta_\omega}$$

where the values of Δ_0 and Δ_ω are obtained by direct measurement on a suitable photomicrograph. In that way the angle of inclination of pearlite grains may be computed with a sufficient accuracy.

5. When the angle of inclination ω approaches 80 deg. then the distance between the lamellæ Δ_ω becomes five times greater than Δ_0, ten times at 84 deg., and twenty at 87 deg. The aspect of pearlite, as we are accustomed to see it, must exhibit a considerable change on such sections.

6. Examinations of sections of prepared alloys Nos. 1, 8 and 21 confirm these conclusions and prove that the pearlite grains in hypoeutectoid steel (alloy No. 8), eutectoid steel (No. 21), and hypereutectoid (No. 1) show on a section a change in coarseness and character of structure as expected from the equation—

$$\text{Cos } \omega = \frac{\Delta_0}{\Delta_\omega}.$$

7. The value of Δ_0 becomes, therefore, of importance for every pearlite steel, and may be taken as a measure of the thermal conditions during the Ar1 transformation. A direct way of measuring Δ_0 for values not under $\frac{1}{4}$ μ is given, and another method, based on the formula—

$$\Delta_0 = \Delta_\omega \text{ cos } \omega \text{ or}$$
$$= \frac{\Delta_\omega}{\text{sec } \omega}$$

is recommended for smaller values.

It is suggested that Δ_0 may be taken as one of the characteristics of steels, and that values of Δ_0 might be computed to determine various kinds of pearlite and sorbite pearlite.

8. The following values for Δ_0 are obtained by the direct method:

$$\Delta_0 \text{ (1)} = 1{\cdot}25\ \mu$$
$$\Delta_0 \text{ (8)} = 0{\cdot}35\ \mu$$
$$\Delta_0 \text{ (21)} = 0{\cdot}30\ \mu.$$

As the pearlite of the alloy No. 1 is exceptionally coarse the two last figures are taken as being fairly close to the usual values of Δ_0 met with in practice. The micromillimetres then will read:

$$\Delta_0 \text{ (8)} = 350\ \mu\mu$$
$$\Delta_0 \text{ (21)} = 300\ \mu\mu.$$

By the indirect method the Δ_0 is determined for one of Sir Robert Hadfield's steels. For that steel

$$\Delta_0 \text{ (H)} = .00\ \mu\mu.$$

9. As the diameter of a cementite (d_c) lamella may be taken as one-third, or better one-fourth, of the total distance between the lamellæ

$$d_c = \tfrac{1}{4}\ \Delta_0,$$

the following values were obtained:

$$d_c \text{ (8)} = 90\ \mu\mu.$$
$$d_c \text{ (21)} = 75\ \mu\mu.$$
$$d_c \text{ (H)} = 25\ \mu\mu.$$

Assuming that the diameter of the grain D = 100 Δ_0, the cementite lamellæ are represented as films and a suggestion is made as to the interior structure of the pearlite grain.

THE PHYSICAL SOCIETY OF LONDON.

AT the meeting of the Physical Society of London, held on April 28, at the Imperial College of Science, Dr. Alexander Russell, M.A., D.Sc., in the chair, a paper on "*The Position of Best Focus in the Presence of Spherical Aberration*," by T. Smith, B.A., F.Inst.P., National Physical Laboratory, was read by Mr. J. Guild, in the absence of the author. In this paper focal variations of phase in the presence of spherical aberration are calculated directly from the axial intersection points of rays of known inclination, and the graphical method employed shows that the focus for which phase variations have a minimum value may be found and suitably interpreted when the finiteness of the wave-length is disregarded. The diagrams here employed for the representation of spherical aberration have advantages over the more usual diagrams in several important particulars, and it is suggested that the older forms should be abandoned.

Discussion.—Mr. J. Guild: The position of best focus is usually defined in geometrical optics as that of the circle of least confusion, but the geometrical definition adopted by the author makes it coincide with the region of maximum density of the rays. This view is interesting in connection with modern theories of vision, such as that of Professor Joly, of Dublin, according to which vision is due, not to a two-dimensional stimulation of the surface of the retina, but to a photo-electric effect, which operates in depth throughout the volume of the visual purple. On this view the author would be right in identifying the focus with the region of maximum concentration of energy. It is of interest to know what would be the difference in practical effect between the two definitions; it seems as though it might be appreciable in some cases.

Mr. F. Twyman: The search for a definition of the position of best focus arises from the desire to reduce to rigorous quantitative terms one's empirical estimate of the effectiveness of a lens. Unfortunately, those who have to use lenses will not be satisfied with a theoretically optimum design, but prefer that one of a number of lenses which seems to give the best results on trial. I am much struck by the last speaker's ingenious suggestion as to the volume-stimulation of the retina, but I doubt if there would be any appreciable difference in practical effect between the various definitions of focal length.

Lieutenant-Colonel J. W. Gifford (communicated remarks): From the point of view of trigonometrical trace, I have long felt that the question of the best height from the vertex for the incident ray at the first surface on which successful calculations can be based must need clearing up. Thanks are due to Mr. T. Smith for his able treatment of the subject from quite a new point of view. In reference to Mr. Smith's Figs. 3 and 4, and diagrams from the geometrical aspect of the same kind in some of the text books, I would like to ask him whether the patterns there shown apply when more than two optical media are used in the construction of the lens combination. That they represent the case for the first surface only, and in a modified form when more than one curved surface and more than one refracting medium exist in the combination, is doubtless the case. But my own experience with apochromatic triples, and their trace, has led me to think that the curves Mr. Smith has drawn would cross and re-cross the ordinate more than twice—indeed, in that case several times—so that there the problem becomes decidedly more complex. A simple practical formula for approximately equal areas which I have found useful is

$$H = \sqrt{\frac{\left(R + \frac{t}{4}\right)^2}{2}} \left| \frac{R}{h} \right.$$

where h is the total height to the edge, t the thickness at the axis for that height, and H the height required. R is the radius of the first surface. This formula gives a somewhat smaller value than Kerber's $H = \frac{h}{2}\sqrt{3}$, which is consonant with the smaller amount of light per unit area transmitted as we approach the edge.

2. A paper on "*The Determination of the Absolute Stress-variation of Refractive Index*," by F. Twyman, F.Inst.P., and J. Perry, was read by Mr. Twyman, who also exhibited the apparatus to which the paper refers. The paper describes a ready method of determining the stress-optical coefficients, the Hilger interferometer being employed. Young's modulus of elasticity and Poisson's ratio are determinable simultaneously. In the discussion Mr. J. Guild inquired what fraction of a band could be counted in the determination of E. The author replied that the bands were counted to the nearest one-tenth.

3. A paper on "*An Experimental Comparison of the Viscous Properties of (a) Carbon Dioxide and Nitrous Oxide, and (b) Nitrogen and Carbon Monoxide*," by C. J. Smith, B.Sc., A.R.C.S., D.I.C., Imperial College of Science and Technology, was read by the author. This paper is the result of an experimental investigation to determine the viscous properties of (*a*) carbon dioxide and nitrous oxide, and (*b*) nitrogen and carbon monoxide. Direct comparisons have been made in each case by observing the time required by a mercury pellet to force an equal volume of gas through a capillary tube, at atmospheric and steam temperatures. For the above groups of gases, the times of fall for each gas are equal at 15 deg. and 100 deg. C., and hence, independently of any knowledge of the absolute viscosity, it has been proved that the viscous properties are identical over the above temperature range. The absolute viscosity has been obtained by comparison with air, and the mean area of collision deduced by using Chapman's formula.

Discussion.—Professor A. O. Rankine: The author, who has worked with praiseworthy perseverance, has succeeded in establishing beyond dispute a close identity in viscous properties between the two pairs of gases investigated. The ratios of the viscosities have been measured with an extremely high accuracy, since they are the ratios of times which are practically equal. It is remarkable that gases which resemble one another so closely in their physical properties should differ so widely in other—*e.g.*, their physiological properties. It seems clear that chemical and physiological properties are determined by the nuclei, and are independent of the outer electron system. A further curious fact has been brought to light—viz., that the surface tension of mercury is the same when in contact with various gases which differ widely in other respects, while its value in presence of CO_2 is very different from that in presence of N_2O Dr. Percy Phillips, in an unpublished investigation, attempted to obtain the variation of the viscosity of N_2O in the neighbourhood of the critical state, but failed because the angle of contact of the mercury with the glass became 180 deg., whereas no such difficulty had arisen in the case of CO_2, near the critical state.

Dr. D. Owen congratulated the author on his work, the interest of which arose from the connection which the viscosity of a gas bore to the size and shape of the molecule. The author remarks that all theories of atomic structure which identify the electron system of the molecule of N_2 with that of CO can equally claim the support of his results. But since the Lewis-Langmuir theory does lead to a close equality in structure in the case of the gases in question, it seemed fair to place the agreement found in the present paper to the credit of that theory. In regarding theories of the atom and molecule, one wondered whether there were certain properties only explicable on a statical theory and others requiring a dynamical theory; one was reminded of the apparent antinomy in the province of radiation between the undulatory and the quantum theories. The accuracy obtained by the device of splitting the mercury pellet—viz., 0·2 per cent.—is remarkably good. Even in very carefully cleaned tubes it appears that the correction in the case of a single pellet may amount to 4 per cent., and it is subject of congratulation that by the device of splitting the pellet this has been reduced to $\frac{1}{2}$ per cent. He would like, in conclusion, to ask the author whether he could give a simple physical interpretation of Sutherland's constant—which has the dimensions of a temperature, and which appeared so constantly in relation to subjects like that of the present paper.

Dr. F. Ll. Hopwood, remarked that physiological properties may depend not on the nuclei but (as suggested by Dr. Hambourg) on the shape of the molecule; whereas the author's results concern the mean collisional area of the molecule, not its shape.

Mr. R. S. Whipple suggested that a photographic method might be of advantage in measuring the time of fall of the pellets.

Dr. H. P. Waran: I would suggest that the difficulty which the author experienced in obtaining nitrogen free from ammonia was due to his using too strong a solution of the latter. My original apparatus can be modified by providing a side tube near the tube C, Fig. 2, and maintaining a steady flow of the reacting liquids into and out of the apparatus. Very dilute ammonia can then be used, and the trace of this substance in the resulting nitrogen will be so small that it can be absorbed along with the water vapour by the acid phosphorus pentoxide in the bulb between K and D, the parts E, F, being dispensed with. Nitrogen thus obtained is spectroscopically pure, and any quantity can be generated.

Dr. J. S. G. Thomas: The measurement of viscosity is of such importance to gas technologists that results over a wider range of temperature would be very valuable. For instance, the work of Stanton and Pannell on flow in gas pipes demands a knowledge of the variation of viscosity up to 600 deg. C. It would also be interesting to know how the viscosity of a mixture of gases depends on that of its constituents. The attempt to estimate the former from the latter gives discordant results in practice.

4. An *Optical Sonometer* was exhibited in action by Mr. F. Twyman, A.I.E.E., F.Inst.P. (A. Hilger, Limited). The object of this instrument is to furnish graphs of the pressure variation in sound waves. The sound is directed by a trumpet upon a celluloid membrane a fraction of a wave-length of light in thickness, which is silvered at a point between its centre and periphery. Rays from a pointolite lamp are concentrated on the silver surface, and are reflected thereby through an ordinary and a cylindrical lens on to a photographic strip carried by a spring-driven chronographic drum. The duration and incidence of the photographic exposure are controlled by adjustable devices revolving with the drum. The constants of the membrane can be determined by measuring its curvature with an interferometer when it is being stressed by gravity, pneumatic pressure or electrostatic attraction. Good, sound records can be obtained so long as the pitch of the sounds investigated differs considerably from the resonance pitch of the membrane, which is of the order of 200 per second.

THE DURATION OF COLLISIONS.—In a paper published in the *Physical Review* for last December, Mr. E. W. Tschudi describes experiments on the duration of the contact between colliding balls and cylinders. The duration of the contact was estimated from the charge of electricity acquired by a condenser, the circuit supplying which was closed when the bodies came into collision and broken when they separated. In this way Mr. Tschudi found that when a 3-inch cast-iron ball moving with a velocity of about 38 in. per second struck a similar ball, the duration of the contact was 0·00033 sec. When the speed was reduced to about 5½ in. per second, the time of contact was increased to 0·00058 sec.